PUBLICATIONS

OF THE

ASTRONOMICAL SOCIETY

OF THE PACIFIC.

(FOUNDED FEBRUARY 7, 1889.)

VOLUME I.

1889.

SAN FRANCISCO:
PRINTED FOR THE SOCIETY.
1889.

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CORRIGENDA.

Page 46; Insert a star (*) to signify life-membership after the following names, viz: CHARLES GOODALL, HORACE L. HILL, D. O. MILLS.

Page 51; line 12; *for* 5 × 7 *read* 4 × 5.

Page 70; Column "Star"; *for* W. H. Z. *read* W. M. Z.

Page 85; line − 9; *for* TERRY *read* TORREY.

Page 85; line − 24; *for* Centreville *read* Warm Springs.

Page 85; line − 27; *add* to Mr. BOULTON'S address, (Box 2015, New York City).

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

No. 1. San Francisco, California, February 7, 1889.

The Society was organized at a meeting held February 7, 1889, and the distribution of the following Circular was ordered. The list of present members is given on page 2. The following officers *pro tem.* were chosen to serve till the annual election on March 30th, next:

EDWARD S. HOLDEN (Lick Observatory), - - - - -	PRESIDENT
J. M. SCHAEBERLE (Lick Observatory), - - - - - -	SECRETARY
C. BURCKHALTER (Chabot Observatory, Oakland), - -	SECRETARY
E. J. MOLERA (850 Van Ness Ave., San Francisco), - - - -	TREASURER

CIRCULAR.

San Francisco, February 7, 1889.

My Dear Sir: — The cordial co-operation of many amateur and professional astronomers in the very successful observations of the Solar Eclipse of January 1, 1889, has again brought forward the desirability of organizing an Astronomical Society of the Pacific, in order that this pleasant and close association may not be lost, either as a scientific or as a social force. You are respectfully invited to become a member of this organization, and to do your part towards making it useful in our community.

The new Society is designed to be popular in the best sense of the word. We wish to count in our membership every person on the Pacific Coast who takes a genuine interest in Astronomy, whether he has made special studies in this direction or not, and we believe that every such person will get, and feel that he gets, a full return from the Society, either from its publications or from its meetings.

You will observe that the seat of the Society (the place of deposit of its library, collections, etc.) is in San Francisco, where rooms can doubtless be found. Half of the meetings of the Society are to be held there (including the annual meeting). The other half are proposed to be held at the Lick Observatory, on certain Saturdays of the summer months when clear weather is to be expected. It will be easy for the members to organize a trip (at excursion rates) from San Francisco to the Lick Observatory, leaving San Francisco

at 8:30 A. M., and arriving at the Lick Observatory at 4 P. M. A business meeting can be held before 7 P. M.

At 7 P. M. on Saturdays the telescopes of the Observatory are put at the disposition of all visitors, and thus actual demonstrations from the heavens can be made of subjects of discussion.

It would seem that, in this way, a vivid interest in our science can be created and maintained, and that a Society possessing such exceptional advantages ought to grow and prosper, and be of real weight in the advancement and in the diffusion of knowledge. We should look forward to the establishment of an astronomical journal of high class, to the formation of a special astronomical library, and especially to the organization of such scientific work as requires co-operation and mutual assistance.

Invitations to join the Society have been sent and are hereby extended to each member of the California Academy of Sciences, Technical Society, Microscopical Society, Pacific Coast Amateur Photographic Association, Geographical Society of the Pacific, San Diego Society of Natural History, California Historical Society; to each person who is known to have made observations of the Solar Eclipse of January 1, 1889; to the President and Faculties of the Colleges, Normal and High Schools of California; and to the officers of the Government Surveys in California.

Very faithfully yours,

E. J. MOLERA, San Francisco.
A. P. REDINGTON, "
GEO. W. REED, "
C. L. GODDARD, "
O. V. LANGE, "
F. H. MCCONNELL, "
S. C. PARTRIDGE, "
W. H. LOWDEN, "
E. W. RUNYON, "
WM. BOERICKE, "
W. A. DEWEY, "
F. R. ZIEL, "
WM. M. PIERSON, "
CHASE GITCHELL, "
GEORGE TASHEIRA, "
V. J. A. REY, "
A. J. TREAT, "
J. H. JOHNSON, "
S. C. PASSAVANT, "
W. B. TYLER, "
WM. IRELAN, San Francisco.
C. BURCKHALTER, "
ED. GRAY, "
W. C. GIBBS, "
C. P. GRIMWOOD, Fruitvale,
E. S. HOLDEN, Lick Observatory.
S. W. BURNHAM, "
J. M. SCHAEBERLE, "
J. E. KEELER, "
E. E. BARNARD, "
C. B. HILL, "
J. R. JARBOE, San Francisco.
P. R. JARBOE, "
JOHN LE CONTE, Berkeley.
I. STRINGHAM, "
F. SOULÉ, "
T. GUY PHELPS, Belmont.
ARTHUR RODGERS, San Francisco.
WM. NORRIS, "
C. WEBB HOWARD, "

BY-LAWS

OF THE

ASTRONOMICAL SOCIETY OF THE PACIFIC.

(Adopted February 7, 1889.)

ARTICLE I.

This Society shall be styled the ASTRONOMICAL SOCIETY OF THE PACIFIC. Its object shall be to advance the Science of Astronomy, and to diffuse information concerning it.

ARTICLE II.

This Society shall consist of Active, Life, Corresponding and Honorary members.

1. Active members shall consist of persons who shall have been elected to membership, and shall have paid their dues as hereinafter provided.

2. Life members shall consist of persons who shall have been elected to life membership and shall have paid $50 (fifty dollars) to the Treasurer of the Society.

3. Corresponding members shall consist of persons not residing on the Pacific Coast, who shall have been elected by the Society as such.

4. Honorary members shall consist of persons specially distinguished for their attainments in Astronomy, who shall have been elected to honorary membership.

Corresponding and Honorary members shall pay no dues, shall not be eligible to office, and shall have no votes.

ARTICLE III.

At each annual election there shall be elected a Board of eleven Directors, and a Committee on Publication consisting of three members. The officers of this Society shall be a President, three Vice-

Presidents, two Secretaries and a Treasurer. The Directors shall organize immediately after their election and elect from their number the officers of the Society. They may also appoint a Librarian, and such other assistants as may be required.

The Library of the Society shall be kept in San Francisco, and shall be open to the use of all the members.

ARTICLE IV.

The President, or, in his absence, one of the three Vice-Presidents, or, in the absence of both the President and the Vice-Presidents, any member whom the Society may appoint shall preside at the meetings of the Society. It shall be the duty of the President to preserve order, to regulate the proceedings of the meetings, and to have a general supervision of the affairs of the Society.

ARTICLE V.

The Secretaries shall keep and have the custody of the records; they shall have the custody of all other property of the Society, excepting the money thereof; they shall give timely notice of the time and place of meetings; they shall keep in books a neat and accurate record of all orders and proceedings of the Society, and properly index them; they shall conduct the correspondence of the Society; they shall preserve and index the originals of all communications addressed to the Society; and keep a copy of all their letters, properly indexed; and they shall prepare for publication an accurate summary of the transactions of the Society at each of its meetings.

ARTICLE VI.

The Treasurer shall receive and deposit in such bank as may be designated by the Directors, to the credit of the Society, all donations and bequests of money and all other sums belonging to the Society. He shall keep an account of all money received and paid by him, and at the annual meeting render a particular statement of the same to the Society. Money shall be paid by him only on the written order of the Finance Committee of the Board of Directors.

ARTICLE VII.

Candidates for membership may be proposed at any meeting, and voted for at any subsequent meeting. The vote shall be by ballot,

and a majority of the members present shall be required for an election.

ARTICLE VIII.

Each active member shall pay an annual subscription of five dollars, due on the first of January of each year, in advance. Each active member shall, on his election, pay into the Treasury of this Society the sum of five dollars, which shall be in lieu of the annual subscription to the first of January following his election. No one shall be deemed an active member, or receive a diploma, until he has signed the register of members, or accepted his election to membership in writing, and paid his dues for the current year. Any member may be released from annual dues by the payment of fifty dollars at one time, and placed on the roll of life members by the vote of the Board of Directors. Any failure on the part of a member to pay his dues within six months after the time the same shall have become payable, shall be considered equivalent to a resignation.

ARTICLE IX.

The annual meeting of this Society shall be held on the last Saturday in March at eight o'clock P. M., at the rooms of the Society in San Francisco; and bi-monthly meetings shall be held on the last Saturday of each alternate month, for the ordinary transactions and purposes of the Society, as follows:

The meetings for the months of May, July and September shall be held in the Library of the Lick Observatory, Mount Hamilton, at a suitable hour; and the meetings for January, March and November shall be held in the rooms of the Society, in San Francisco, at eight o'clock P. M.

A special meeting may be called by the President, or, in his absence or disability, by one of the Vice-Presidents; or, in the absence or disability of both the President and the Vice-Presidents, by the Secretary, on the written requisition of ten active members; and the object of such meeting shall be stated in the notice by which it is called.

The annual election shall be held on the day of the annual meeting, during such hours as the Directors may appoint.

Only active and life members shall be permitted to vote at any meeting of the Society, and no one shall vote who has not paid all his dues for past and current years.

ARTICLE X.

Ten active or life members shall be a quorum for the transaction of business.

ARTICLE XI.

No papers or manuscripts shall be published by the Society without the consent of the Directors. Any motion to print an address, or other paper read before the Society, or any other matter belonging to the Society, shall be referred to the Committee on Publication, who shall report to the Directors. The Committee on Publication may make suggestions to the Directors, from time to time, with reference to the publication of such papers as in their judgment should be published by the Society; and this committee shall have the care, direction and supervision of the publication of all papers which the Directors may authorize to have published.

Members of the Society shall receive all the publications of the Society free of charge.

ARTICLE XII.

This Society may, by a vote of the majority of all its active and life members, become a branch of an American Astronomical Society, should one be formed.

ARTICLE XIII.

It shall be the duty of the Directors, in case any circumstances shall arise likely to endanger the harmony, welfare or good order of the Society, to call a special meeting of the Society; and if, at such meeting, after an examination of the charges, and hearing the accused, who shall have personal notice of such proceedings, it shall be proposed that the offending member or members shall be expelled, a vote by ballot shall be taken, and if two-thirds of the members present vote in favor thereof, the offending member or members shall be expelled.

ARTICLE XIV.

The Directors shall meet one hour before the stated time of each bi-monthly meeting, and at such other times as they may appoint. The President, or in his absence, any one of the Vice-Presidents, may call special meetings of the Board of Directors at any time. Notice of the time and place of such meeting shall be given by the

Secretaries, by depositing in the postoffice at San Francisco, a notice of the time and place, addressed to each Director personally, at his last known place of residence, with the postage thereon prepaid, six days before the time of meeting.

ARTICLE XV.

The By-Laws may be amended at any time by a consenting vote of nine members of the Board of Directors at any regular meeting thereof.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

No. 2. San Francisco, California, March 30, 1889.

THE WORK OF AN ASTRONOMICAL SOCIETY.

Address delivered before the Astronomical Society of the Pacific, March 30, 1889, by Edward S. Holden, LL. D., *Director of the Lick Observatory.*

In the year 1820 the state of Astronomy in England was somewhat as follows: The Royal Observatory at Greenwich was pursuing its regular routine observations of the positions of the sun, moon and stars under the direction of the Astronomer Royal, Pond, whose chief service to Astronomy consisted in the minute accuracy of his observations and in the faithfulness with which they were amassed and discussed. His controversy with Brinkley (Astronomer of the Dublin Observatory) on the latter's determination of stellar parallaxes, cleared the way for the great researches of Bessel and Struve on the same subject, which followed a dozen years later. The Radcliffe Observatory at Oxford was in operation, but no observations were published. The Cambridge Observatory was just founded. The Observatory at Edinburgh was barely built, and was not yet a public institution. The Armagh Observatory had no instruments of importance and was doing no work. Groombridge's private observatory at Blackheath was busy with his catalogue of 4243 circumpolar stars. Sir William Herschel, the greatest of practical astronomers and the glory of England (then 82 years old), was resting from his labors. His son, Sir John Herschel, had not yet begun that long series of observations which has made his name illustrious.

On the Continent, the magnificent labors of Bessel, Gauss, Olbers and Struve were laying the foundations of the science of to-day. The spirit of their methods made itself known in England and deeply affected some of the younger men at the universities—notably Babbage, Dean Peacock, and Sir John Herschel. These three entered into a compact, which was most fruitfully carried out, "to leave the world wiser than they found it." One of the most important results of this resolution was the founding of the Royal Astronomical Society of London—an institution which has done incalcu-

lable good in fostering the science of Astronomy, not only in England, but throughout the whole civilized world. It is not part of my purpose to trace the influence of this society, nor to show in detail what its work has been. I rather wish to quote here a few paragraphs from the "Address of the Society, Explanatory of their Views and Objects," which was circulated in the year 1820, at the time of its foundation. And I wish to do this for two reasons; because, first, the need of such an association in our own midst is much the same as that felt by HERSCHEL and BABBAGE in England sixty years ago; and, secondly, because the programme of this society may point out to us along what lines we should proceed to make our own newly formed Astronomical Society equally useful in its own sphere.

The times have changed since then, no doubt. The immediate problems of Astronomy are different; but the spirit of the methods by which they are to be attacked and solved is eternally the same; and the need for co-operation and concentration of forces is more and more pressing as the complexity of processes becomes greater and greater.

I ask you, then, to listen to a few brief extracts from the first printed paper of the Royal Astronomical Society, and to imagine to yourselves the state of English Astronomy of that day, when the elder HERSCHEL had finished his work, and when the host of English amateurs of to-day was represented by GROOMBRIDGE, toiling at the observations and the reductions of his polar catalogue:

"In a country like Great Britain, in which the sciences in general are diligently cultivated, and *Astronomy* in particular has made extensive progress and attracted a large share of attention, it must seem strange that no society should exist peculiarly devoted to the cultivation of this science; and that Astronomy, the sublimest branch of human knowledge, has remained up to the present time unassisted by that most powerful aid; and has relied for its advancement on the labors of insulated and independent individuals.

"It may be conceived by some that Astronomy stands less in need of assistance of this kind than any other of the sciences; and that, in the state of perfection which its physical theory has already reached, its ulterior progress may safely be intrusted to individual zeal and to the great national establishment exclusively appropriated to celestial observations; or, at all events, to those public institutions and academies in all civilized nations whose object is the general cultivation of the mathematical and physical sciences. It may therefore be necessary to state the useful objects which may be accomplished, and the impediments which may be removed, by the formation of a society devoted solely to the encouragement and promotion of Astronomy.

"Owing to the great perfection which the construction of optical instruments has attained in England, and the taste for scientific research universally prevalent, there have arisen in various parts of the kingdom a number of private and

public observatories, in which the celestial phenomena are watched, and registered with assiduity and accuracy, by men whose leisure and talents peculiarly adapt them for such pursuits; while others, with a less splendid establishment, but by the sacrifice of more valuable time, pursue the same end with equal zeal and perseverance. Considerable collections of valuable observations have thus originated; by far the greater part of which, however, owing to the expense and difficulty of publication and various other causes, must inevitably perish, or at least remain buried in obscurity, and be lost to all useful purposes, unless collected and brought together by the establishment of a common center of communication and classification, to which they may respectively be imparted.

"This great desideratum, it is presumed, will be attained by a society founded on the model of other scientific institutions, having for one of its objects the formation of a collection or deposit of manuscript observations, etc., open at all times for inspection, to which the industrious observer may consign the results of his labors, with the certainty of their finding a place, among the material of knowledge so amassed, exactly proportioned to their intrinsic value. At the same time it will thus be rendered practicable to form a connected series from a mass of detached and incomplete fragments; and the society will render a valuable service to science, by publishing, from time to time, from this collection, such communications or digests as seem calculated, by their nature and accuracy, either to supply deficiencies or to afford useful materials to the theoretical astronomer.

* * * * * * * *

"It is almost unnecessary to enumerate the advantages likely to accrue from the encouragement which an Astronomical Society may hold out; but among others may be mentioned the perfecting of our knowledge of the latitudes and longitudes of places in every region of the globe; the improvement of the lunar theory, and that of the figure of the earth, by occultations, appulses, and eclipses simultaneously observed in different situations; the advancement of our knowledge of the laws of atmospherical refraction in different climates, by corresponding observations of the fixed stars; the means of determining more correctly the orbits of comets, by observations made in the most distant parts of the world; and, in general, the frequent opportunities, afforded to a society holding extensive correspondence, of amassing materials which (though separately of small importance) may by their union become not only interesting at the present time, but also valuable as subjects of reference in future.

"By means of corresponding members, or associates, in distant countries, the society may hope to unite the labors of foreign observers with their own; and by thus establishing communication with eminent astronomers and institutions in all parts of the world, to obtain the earliest intelligence of new discoveries and improvements, which it may, perhaps, be desirable to circulate among such of its members as may profess themselves anxious to receive it, without loss of time.

"The circulation also of notices of remarkable celestial phenomena about to happen (with a view to drawing the attention of observers to points which may serve important purposes in the determination of elements or coefficients) may form another, and perhaps not the least interesting object of the society. To have the same phenomena watched for by many observers is the only sure way of having them observed by some; and moreover, the attention of an astronomer may frequently be aroused by a formal notice, especially when accompanied with directions for observing the phenomenon in the most effective way, when prob-

ably the mere ordinary mention of it in an ephemeris might fail to attract his observation.

"One of the collateral advantages of a society including many practical astronomers among its members (but which will appear of no small importance to those who possess good instruments) will be the mutual understandings which will be propagated among amateur astonomers, by frequent meetings and discussion, as to the relative merits of their instruments; and as to the talents and ingenuity of the various artists, both of our own and of foreign nations; not to mention the emulation which this must naturally excite to possess the best instruments; and the consequent tendency of such discussion towards a further improvement in their construction, or to the discovery of new ones.

"As the extent of the funds of the society must depend on the number of its members, it is impossible to conjecture at present how far its views respecting their application may extend. Besides the ordinary expenses attending an institution of this nature, the annual or occasional publication of communicated observations; the payment of computers employed in the reduction and arrangement of observations, or in computing the orbits of new planets, comets or other interesting bodies; the formation of an extensive astronomical library, not only of manuscripts, but also of printed books; and perhaps, at some future period, the proposals of prizes for the encouragement of particular departments of the science, either theoretical or practical, or for the improvement of astronomical instruments or tables, may be mentioned as worthy objects on which they may be bestowed.

"Such are the principal considerations which have actuated a number of individuals to form themselves into a society, under the name of the *Astronomical Society of London*, and to give this publicity to their determination, with a view of inviting others to unite in the prosecution of their plans. They have at the very commencement met with the most flattering success, which induces them to hope that, in a short time, every assiduous cultivator of the science will be found to have added his name to the list of members.

"The objects of the original members may be sufficiently gathered from what has been already said, and may be thus summed up in a few words, viz: to encourage and promote their peculiar science by every means in their power, but especially, by collecting, reducing and publishing useful observations and tables, by setting on foot a minute and systematic observation of the heavens, by encouraging a general spirit of inquiry in practical Astronomy, by establishing communications with foreign observers, by circulating notices of all remarkable phenomena about to happen and of discoveries as they arise, by comparing the merits of different artists eminent in the construction of astronomical instruments, by proposing prizes for the improvement of particular departments, and bestowing medals or rewards on successful research in all; and, finally, by acting as far as possible in concert with every institution, both in England and abroad, whose objects have anything in common with their own; but avoiding all interference with the objects and interests of established scientific bodies."

In our own case, we must remember how various are the opportunities and attainments of our different members, and try to lay the foundations of our efforts so broadly that every class will find a sphere of action in our programme, a stimulus in our proceedings, and a

support in our friendly association. The few professional astronomers in our midst will here lose that sense of intellectual and professional isolation which is a drawback and a danger. Nothing that is clearly conceived is too technical to be placed before an assemblage of intelligent men, and the very effort to explain gives a lucidity to the original conception which it might otherwise lack. There is a moral force, too, in knowing that one does not need to wait for sympathetic appreciation, but that it is to be found every day and all around one. The opportunity to communicate the results of one's work readily and quickly is of the highest value; and "the end of all observation is communication."

By far the greater number of our members will be amateurs, and here again we must recognize the fact that there are many classes with many differing opportunities and means for work and study. Some among us already possess telescopes of no inconsiderable power. In 1820, there was no refractor in Europe more powerful than the 5-inch telescope with which HERSCHEL and SOUTH observed their double stars. It should be the aim of the society to point out the directions in which such instruments can be used, so that either some useful result will be attained for the science, or so that, at least, the maximum amount of pleasure and personal profit can be had by the owners. I presume there are few amateurs who have not experienced a sense of disappointment in the use of their telescopes. It is not that the heavens are less glorious, nor that the observer is less devoted and enthusiastic, but it is because he often comes to feel that there is an aimlessness in his work which he finds to be disheartening. If at this moment some word or hint can be given to him which will show him how to employ his time and energies to some real advantage, either to science or to himself, the old enthusiasm will return and the labor will again become delightful. It is precisely such words and such hints that he may expect to find here among his colleagues.

There is an important class of our amateur members whose photographic experience and skill can bear the most useful fruits if they are directed toward certain astronomical ends. We also have professional astronomers among us, whose photographic knowledge is second to none. The association which this society makes easy and puts into an organized form, has already led to important results in the observations of the Solar Eclipse of last January by photographic means, and will, no doubt, continue to be fruitful. There are many other fields of research open to this method of observation.

We have other members, also, who have no apparatus for observation, but who have the ability, the leisure and the desire to forward Astronomy by computing the observations of others. There is a boundless field for such amateurs, and I am not sure that their efforts, if rightly directed, might not be of more real importance than any others. The Lick Observatory alone could provide the observations to keep a score of computers busy, and this work could be so selected as to be of all grades of difficulty and to employ every variety of talent.

Finally, we have among us those who have joined as learners; who are here to listen, to observe, to read and to study. They, in turn, should find in our meetings what they seek for and require. Their reading and their study can be guided, and it is among them that we may look for our workers after the next few years. Every class of talent and opportunity ought to find its profit either in our meetings or in our publications.

One word with regard to the conduct of our meetings. My own experience in scientific societies has led me to think that their meetings should never consist of mere lectures, no matter how interesting. There should be discussion, questions, remarks, interchange of ideas, contact of active minds. Let each member feel that he has a part to bear, both in the actual meetings and outside of them, among his associates. In one word, let our society be a live one—active, intelligent, modest, competent. It has a doubled interest in its two-fold place of meeting. The astronomers of the Lick Observatory can promise that the meetings held at Mount Hamilton shall be interesting and fruitful. The meetings held in San Francisco will also be full of interest.

One of the chief uses of the society will be to make an astronomical library available to the amateur observer. We have already made a beginning in this direction. It is not necessary that our collection should be very extensive. A complete astronomical library would contain, perhaps, 20,000 volumes. But it is desirable that we should own a full set of the most important astronomical journals. The progress of the science can be traced in their pages from day to day, and their past volumes give its history.

I have thought it worth while to give in a list which follows the titles of the more important astronomical periodicals, and I have ventured to add the names of some twenty or thirty books which our members would do well to own personally. It is not necessary to buy all of them at once, but the possession of one will lead to the

desire for another, as the scope of observation or of reading is enlarged. The society library should begin by owning these volumes. It will grow subsequently as our wants develop, both by purchase and by exchange with other scientific institutions:

Astronomical Journals.

Astronomische Nachrichten (established 1821); 2 vols. a year. Kiel; price, $8.00.

Astronomical Journal (established 1851). Cambridge, Mass.; $5.00.

Bulletin Astronomique (established 1884). Paris; $4.75.

L'Astronomie (established 1882). Paris; about $3.75.

The Observatory (established 1877). London; $3.50.

Ciel et Terre (established 1880). Brussels; $2.60.

Himmel und Erde (established 1888). Berlin; $5.00.

Sirius (established 1868). Leipzig; $2.60.

Wochenschrift für Astronomie (established 1847). Halle; $2.70.

The Sidereal Messenger (established 1882). Northfield, Minn.; $2.00.

Nature. London; $6.00.

La Nature. Paris; $6.00.

The Companion to the Observatory. London; published annually; 1s. 6d. [This latter work will take the place to the amateur observer which the *Nautical Almanac* holds to the professional.]

Publications of Astronomical Societies.

Publicationen der Astronomischen Gesellschaft. Leipzig; 4to (at irregular intervals).

Vierteljahrsschrift der Ast. Gesell. Leipzig; quarterly.

Memoirs and Monthly Notices of the Royal Astronomical Society. London; yearly and monthly.

Journal of the Liverpool Astronomical Society. Liverpool; monthly.

Bulletin de la Société Astronomique de France. Paris; yearly (?).

Publications of the Astronomical Society of the Pacific. San Francisco.

List of Some Books of Reference in Astronomy.

Houzeau: Vade Mecum de l'Astronome; 8vo.

Wolf: Geschichte der Astronomie; 8vo.

Delaunay: Cours Elémentaire de l'Astronomie; 12mo.

Loomis: Treatise on Astronomy; 8vo.

Chauvenet: Spherical and Practical Astronomy; 8vo; 2 vols.

Ball: Elements of Astronomy; 12mo.

Young: General Astronomy; 8vo.

HERSCHEL: Outlines of Astronomy; 8vo.
ARAGO: Astronomie Populaire; 8vo; 4 vols.
FLAMMARION: Astronomie Populaire; 8vo.
NEWCOMB: Popular Astronomy; 8vo.
WEBB: Celestial Objects for Common Telescopes; 12mo.
OLIVER: Astronomy for Amateurs; 12mo.
PROCTOR: The Sun; 8vo.
PROCTOR: The Moon; 8vo.
PROCTOR: Saturn and His System; 8vo.
LEDGER: The Sun, Its Planets and Their Satellites; 8vo.
WATSON: A Popular Treatise on Comets, etc.; 12mo.
SMYTH: Celestial Cycle; 2d ed.; revised by Chambers; 8vo.
KLEIN: Star-Atlas (translation by MCCLURE.)
GLEDHILL: Handbook of Double Stars; 8vo.
CHAMBERS: Descriptive Astronomy; 8vo.
GRANT: History of Physical Astronomy; 8vo.
CLERKE: History of Astronomy in the XIX Century; 2d ed.; 8vo.
DELAMBRE: Histoire de l'Astronomie; 4to; 6 vols.

If our own publications are valuable and worthy, they will bring to us through exchanges many works of permanent value. This brings me naturally to the question of what and how much we ought to publish. On this I shall give my own opinion freely, from my personal point of view. It may easily be that my ideas on this question, which are rather positive, require correction. If they do, the experience of the society will be sure to show it.

It seems to me, then, that we should be extremely careful to make our publications fully worthy of the society. Any observation faithfully made and properly recorded well deserves a permanent place. Our very constitution, as a society of amateurs, will usually prevent us from presenting these long series of observations which can be amassed by professional observers in fixed observatories. But we should be careful not to make our publications a vehicle for the expression of mere unsupported opinion. A theory should always be accompanied by its vouchers. I would give more for one careful measure of a double-star, for one faithful observation of a comet, than for pages of speculation regarding the origin of the solar system. Such speculations have their place in science, no doubt, but to be valuable they must follow after years of work. We should make our papers a record of actual work accomplished. There is room, too, *for résumés* of the work of other observers and for papers relating to

the best methods of making our own observations. Important papers in other periodicals may well be translated and printed here. The pages of our journal should be truly representative of the work and thought of the society in general. It would be easy for the Lick Observatory staff to contribute enough material to completely fill such a journal; but it appears to me that, in general, the work of our observatory should appear in abstract only, and that the observations and communications from the amateur members of the society should always constitute the greater part of the publication. At the same time the observatory can serve a very useful end by furnishing a series of abstracts of work done and in progress and by printing notes on work proposed, especially if it is such that our members can co-operate in it. It will be a source of pride to us, if after many years we can look back over what has been printed by the society, and see that every part of it is the record of useful work faithfully done, and possesses a permanent value.

It is for this reason that it seems to me we should not attempt to print at any regular intervals, as monthly or quarterly. Let us keep our papers until we have enough material to form a number of 8, 16, 24 pages, and then issue and distribute this to our members and to our correspondents.

It is tolerably certain that the time has not yet come for us to perform another function of an astronomical society. I refer to the foundation and to the bestowal of the medal of the society as a reward for astronomical work of the highest class. It is certain, however, that in the future, if such a medal were founded, and if it were bestowed only for work of the highest class, as I have said, and never, under any circumstances, to one of our own members, that the responsibility of the award would constitute an important stimulus to the society itself, which would have to judge of the merits of the various works proposed to be rewarded; and that such awards, if always bestowed with judgment and discretion, would soon make the voice of our society respected everywhere. In fact, there is probably no way in which the society could do more good, and in which it could be more quickly influential, than by the bestowal of its medal upon those astronomers whose works fully deserve it. And there is probably no way in which a mistake of judgment would so quickly discredit us, as in the bestowal of our highest award upon insufficient scientific grounds, or for personal reasons.

It is probably quite time that I should leave these general considerations and come to the more special questions of the work which

our members may reasonably expect to do. In any particular case this depends very largely upon the time available for such occupation, upon the instrumental equipment at hand, and upon the individual aptitude and ability. I have already said that for those of us who are willing to calculate the observations made by others, there is an endless variety of work to do, of all grades of importance and difficulty. For those who have only the leisure to interest and divert themselves with observing, there is a rational and useful method to follow, instead of a random one, which will inevitably lead to disappointment. For those who are willing to spend a very little time and money, there are many fields, both old and new, needing cultivation. Let me mention a few of these fields—speaking very briefly of each one:

A very cheap telescope will serve to photograph the sun, provided it be of tolerably long focus. It is highly desirable to obtain enlarged pictures of the solar spots, and to repeat in this country the solar photographs of JANSSEN, which are taken with extremely short exposures—say, from $\frac{1}{1000}$ to $\frac{1}{3000}$ of a second of time. A series of careful counts of the number of new groups and new spots can be made with a very small telescope, and will be very useful. If any one of the society will charge himself with the necessary measurements, we, at Mt. Hamilton, will undertake to furnish daily photographs of the sun on a scale of $4\frac{1}{2}$ inches to the solar diameter for the purpose.

I believe that much can be done by studying the moon's surface with comparatively small telescopes. In such studies I think it desirable to confine the attention to very limited areas, and to study and draw these over and over again, under every possible variety of illumination, until the telescope and the observer can do no more. In this way it may be that only small areas will be covered, but it is certain that our knowledge can be materially increased. The observation of the occultations of stars is most useful, provided the position of the observing station and the local time are accurately known. The Lick Observatory time-signals can be readily made available for this purpose. Probably little can be added to our knowledge of the surface features of the planets by observations with the smaller telescopes. It is, however, well worth the labor for several of our members to maintain a series of observations of the eclipses of the satellites of *Jupiter*. There is nowhere in America, I believe, such a series maintained. The results of this work will be directly comparable with the observations on which the present tables are founded, and constants of reduction can be determined by which these observations can be

employed in conjunction with long series already obtained elsewhere. In this case, as in so many others, our great distance in longitude from the centers of observation, will give to our work a peculiar value. We are eight hours west of Greenwich and three hours west of Washington, and there is no astronomical establishment between us and Japan, and no active observatory between California and Australia. There is a whole field of photometric work (both visual and photographic) which is open to amateurs, and which needs cultivation. I refer especially to the photometry of different portions of the sky under illumination by the sun or by the moon.

Photographs of the planets and neighboring stars of about the same brilliancy on the same plate may very likely be of use in comparing their relative brightness. Should a bright comet appear, no chance should be lost to photograph it, to study the changes in its head, and to map the position of its tail among the stars.

The observations of GOTHARD, on nebulæ, by means of long-exposure photographs have proved that even comparatively small telescopes (provided with driving clocks), properly used, are capable of giving the most brilliant and important results. It is at least possible that the Zodiacal Light, the Milky Way, the Twilight Arch, the Aurora, can be photographed. I know of no direction where the skill of amateur photographers could be better spent than in experiments upon these subjects. The problem is of the same nature as the photography of the faint outlying streamers of the Solar Corona, in which our California amateurs have been so successful.

The field in which amateurs can render the greatest service, however, is in the observation of the variable stars. If these are to be observed by the eye, the use of a mere opera-glass or of a very small telescope is usually sufficient to fix the time of maximum or minimum light with accuracy, by comparisons with neighboring stars which do not vary. Professor PICKERING has already presented to the Society a set of printed instructions for making such observations. If the observer has a photographic telescope or camera, the most elegant and accurate method might be to allow the star's image to *trail* over the plate. When the trail is weakest the star has reached its minimum. A scale of time can be put upon the plate by capping or uncapping the lens at known instants. If the star is too faint to trail on the plate while the latter remains at rest, a very simple clock-work motion can be devised which will cause the telescope to follow the star towards the west at a slow rate. This rate can be so chosen by experiment as to make the *trail* of suitable brightness for measurement.

There are scores of other researches of interest and importance which I have not time to mention and which are well within the reach of amateurs. One competent sextant observer, acting in concert with the Lick Observatory, could render a real service to the geography of the State, with very little expenditure of time and money, by determining the latitudes and longitudes of important points. If such an observer were to fix the positions of the eclipse stations occupied by the various parties on the 1st of last January, he could thus make a positive contribution to science. Mr. KEELER, of the Lick Observatory, has just completed a determination of the position of Norman, for this purpose, as a beginning.

I believe the radiant points of the brighter and more slowly-moving meteors can be accurately fixed by photography, and at any rate the experiment is worth a trial. Statistics of the number of telescopic meteors in different parts of the sky and at different hours are very much needed and are extremely easy to obtain.

I have thus hastily gone over the principal lines along which we, as a society, may hope to work with success. If we undertake all or any of the work thus indicated, and if we carry it on with faithfulness and industry, we may be sure that our efforts will be a veritable aid to science. Whatever we do, let us do thoroughly. Whatever we say, let it be well considered. Let us clearly understand the objects for which we are organized, and let us pursue these with entire confidence. The scope and membership of this society are such that it can have no antagonisms and rivalries with any other. But we may look forward to a career of real usefulness, not only to our members, but to the science of Astronomy. In our own time and way we may hope to make advances in this path, and we may be sure that we can diffuse information in its regard, and help to increase the intelligence, the activity and the pleasure of all our members.

EDWARD S. HOLDEN.

LICK OBSERVATORY, February 15, 1889.

EXTRACT FROM THE MINUTES OF THE ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT 8 P. M., MARCH 30, 1889, AT 605 MERCHANT STREET, SAN FRANCISCO.

(Prepared by the Secretaries for publication.)

The minutes of the meeting of February 7, 1889, were read and approved.

The following named persons (proposed February 7th) were elected to membership: Messrs. WILLIAM ALVORD, J. M. SELFRIDGE, A. O. LEUSCHNER, WILLIAM F. HERRICK, E. M. BIXBY, H. T. COMPTON, C. F. MONTEALEGRE, W. LETTS OLIVER, E. B. JORDAN, JAMES G. JONES, EUGENE FROST, C. MITCHELL GRANT, J. T. WALLACE, T. P. ANDREWS, and Miss ROSA O'HALLORAN.

A Board of eleven Directors and a Publication Committee of three members were elected.

An address on "The Work of an Astronomical Society" was read by Mr. HOLDEN. This is printed in the present number. A paper on "The Solar Corona," by Mr. PIERSON, was received and its reading postponed to the next meeting.

After hearing the reports of the officers *pro tem.*, the Society adjourned to meet at Mount Hamilton, May 25th.

The following resolution was adopted:

Resolved, That the Publications of the Astronomical Society of the Pacific be regularly sent to the following Observatories, etc., and that the Secretaries of the Society be instructed to notify them of this resolution, and to request that they exchange their publications with our own; and that the list of these Corresponding Societies and Observatories be printed in the Publications of the Astronomical Society of the Pacific:

1. Dudley Observatory, Albany, New York.
2. Detroit Observatory, Ann Arbor, Michigan.
3. Royal Observatory, Berlin, Germany.
4. University Observatory, Bonn, Germany.
5. Royal Observatory, Brussels, Belgium.
6. University Observatory, Cambridge, England.
7. Harvard College Observatory, Cambridge, Massachusetts.
8. Royal Observatory, Capetown, Africa.
9. University Observatory, Cincinnati, Ohio.
10. University Observatory, Dorpat, Russia.
11. Royal Observatory, Greenwich, England.
12. Ducal Observatory, Karlsrühe, Germany.
13. University Observatory, Kasan, Russia.
14. University Observatory, Koenigsberg, Prussia.
15. Royal Observatory, Kopenhagen, Denmark.
16. University Observatory, Leiden, Holland.
17. University Observatory, Leipzig, Germany.
18. Royal Observatory, Milan, Italy.
19. Observatory, Melbourne, Australia.
20. University Observatory, Moscow, Russia.
21. Lick Observatory, Mount Hamilton, California.
22. Royal Observatory, Munich, Germany.
23. Carleton College Observatory, Northfield, Minnesota.
24. Radcliffe Observatory, Oxford, England.
25. Savilian Observatory, Oxford, England.
26. National Observatory, Paris, France.
27. Astrophysikalishes Institut, Potsdam, Germany.
28. Imperial Observatory, Pulkowa, Russia.
29. Observatory of the Roman College, Rome, Italy.
30. University Observatory, Stockholm, Sweden.
31. University Observatory, Strassburg, Germany.
32. McCormick Observatory, University of Virginia, Virginia.
33. Naval Observatory, Washington, District of Columbia.

34. Imperial Observatory, Vienna, Austro-Hungary.
35. Royal Astronomical Society, London, England.
36. Liverpool Astronomical Society, Liverpool, England.
37. Astronomical Society of France, Paris, France.
38. Astronomical Society, Chicago, Illinois.
39. Astronomical Society of Germany, Leipzig, Germany.
40. Gesellschaft Urania, Berlin, Germany.
41. National Academy of Sciences, Washington, District of Columbia.
42. Smithsonian Institution, Washington, District of Columbia.
43. California Academy of Sciences, San Francisco, California.
44. Bureau des Longitudes, Paris, France.
45. The Nautical Almanac, London, England.
46. The American Ephemeris, Washington, District of Columbia.
47. Berliner Jahrbuch, Berlin, Germany.

At a meeting of the Board of Directors held immediately after the meeting of the Society, the officers of the Society for the ensuing year were elected. (For list of officers see below.) Mr. WILLIAM ALVORD was elected to life membership. The Secretaries were instructed to correspond with the members of the Society, with a view to ascertain what instruments were in their possession, etc.

OFFICERS OF THE SOCIETY.

EDWARD S. HOLDEN (Lick Observatory),	PRESIDENT
WM. M. PIERSON (76 Nevada Block, S. F.),	VICE-PRESIDENTS
W. H. LOWDEN (213 Sansome Street, S. F.)	
FRANK SOULÉ (Students' Observatory, Berkeley),	
CHAS. BURCKHALTER (Chabot Observatory, Oakland),	SECRETARIES
J. M. SCHAEBERLE (Lick Observatory),	
E. J. MOLERA (850 Van Ness Avenue, S. F.),	TREASURER

Finance Committee—W. C. GIBBS, WM. M. PIERSON, E. J. MOLERA.

Board of Directors—Messrs. ALVORD, BOERICKE, BURCKHALTER, GIBBS, GRANT, HOLDEN, LOWDEN, MOLERA, PIERSON, SCHAEBERLE, SOULÉ.

Committee on Publication—Messrs. DEWEY, TREAT, ZIEL.

NOTICE.

Members are requested to preserve the copies of the *Publications* of the Society as sent to them. At certain intervals a title page and index of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume.

Papers for reading should be sent to either of the Secretaries as early as possible.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with Mr. BURCKHALTER without delay, in order that arrangements may be made for transportation, lodging, etc.

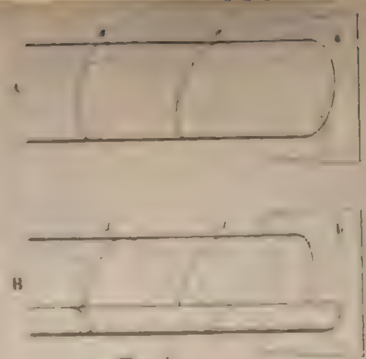

Fig 1

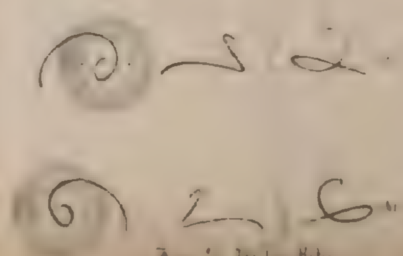

Fig. 2. [illegible]

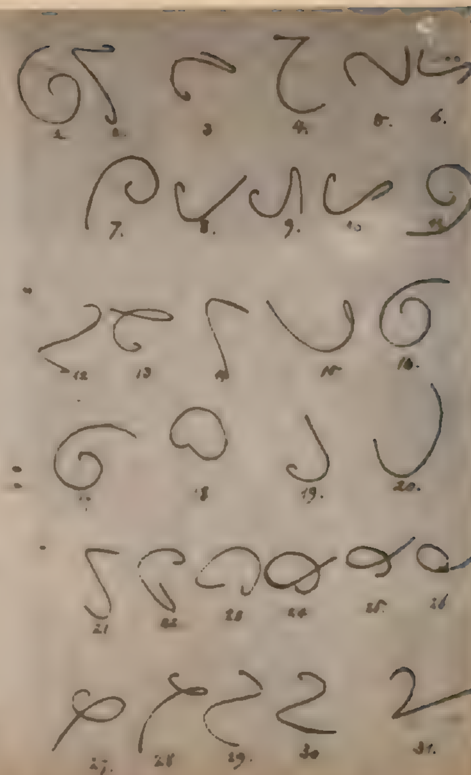

Fig 3.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

No. 3. SAN FRANCISCO, CALIFORNIA, JULY 27, 1889.

ON THE HELICAL NEBULÆ.

By EDWARD S. HOLDEN.

The discovery of the helical appearance of the planetary nebula H. iv. 37 (G. C. 4373) at this Observatory in 1888* naturally led to the search for a method which might enable one, in some cases at least, to determine the actual situation of the different branches of a nebula in space of three dimensions from the data afforded by the projection of these branches upon the background of the sky. In general, this problem is hopelessly insoluble by our present means.

I have, however, obtained some interesting results for one class of nebulæ at least, and perhaps the method employed is capable of wider application.

To understand the method, let us consider how it is that we see a nebula (Plate I, Figure 1). The only data that we have are the outlines *a* of a drawing of the nebula as it is seen projected against the sky. We must conceive the curve *a* to be the base of a cylinder, A, whose elements are straight lines (rays of light) extending from the projection *a* to the eye at A. If the curve *a* is complicated and involved, so will also be the surface of the cylinder A. Any curve whatever which is drawn on the surface of the cylinder (as a', a'',) will be projected into the same curve *a* on the sky; so that the real nebula in space may be any one of the infinite number of curves which can be drawn on the surface of this particular cylinder; for any such curve will be projected into the curve *a*. This is true for any and every nebula, as β, *b*; γ, *c*; δ, *d*, etc., etc. The only thing we really know about the form of a nebula, in general, is that it is projected into a certain shape, as *a*, or *b*, or *c*, or *d*. The problem is to find the true

*See *Monthly Notices* R. A. S. vol. 48, p. 388.

curves, α, β, γ, δ, in space, knowing only the projected curves *a*, *b*, *c*, *d*.

In order to fix the ideas, let us think of the elongated strings of nebulosity which form the spiral nebulæ.

Before going further, it is necessary to remark that the data (the curves *a*, *b*, *c*, *d*) are at present to be obtained only from drawings, and hence they are affected by various classes of errors, due to imperfect telescopic, visual and artistic powers. Photographs of nebulæ are subject to a different and less hurtful class of errors, and they are free from personality. When the great telescope is again in a position to photograph the nebulæ, I shall hope to resume this research with better data. For the present I shall take the drawings of Lord Rosse, of Lassell, and others, as the best available, and shall not concern myself with any errors remaining in them, but shall treat them as correct, since they are the best we have.

To resume consideration of the special problem in hand, let us again examine Figure 1. The only thing we know about the nebula in space is that its projection on the sky is *a*. Any curve on the cylinder A *may be* the true shape of the nebula itself. It is the same for another nebula, *b*, whose curve *b* is usually different from that of *a*. *Any* curve on the surface of B will be projected into *b*. In general, the shapes of the two cylinders are so utterly different that no two identical curves, α', β', can be drawn on their surfaces.

Now, if we should find a pair of curves, *a*, *b*, whose cylinders, A, B, are of such a shape that the same curve *can* be drawn on their surfaces, then there is a certain probability that this identical curve is, in fact, the true shape of each nebula in space. If, again, we can find another nebula, *c*, whose cylinder, C, is so similar to that of *a* that like curves can be drawn on the three surfaces, A, B, C, then there is a still greater probability that the identical curve on the three surfaces, A, B, C, is, in fact, the true shape of these three nebulæ, *a*, *b*, *c*, in space. If we find another nebula, *d*, whose cylinder, D, is of such a shape that we can also draw the same curve on *its* surface, there is a much higher probability that this one curve really represents the true shape of all four nebulæ, *a*, *b*, *c*, *d*, in space.

As we get more and more examples, all fulfilling the same condition, the probability that we have obtained the true shape of the nebulous form in space is very rapidly increased; and

by finding enough examples we may increase the probability to essential certainty; and still more so, if one curve, and only one, can be found which is common to all the projecting cylinders.

We may attack this problem practically, by seeking through trials for a single curve, Φ, which by projection at various angles and in various positions will give all the differing curves, a, b, c, d, e, ... s. If such a curve can be found (by trial), and if only one such curve can be found, it will become more and more probable that Φ is, in fact, the true curve of each nebula, α, β, γ, δ, ... ω, in proportion as more and more curves, a, b, c, d, ... accurately correspond to the different projections of this type curve, Φ. The idea of such types has been suggested to me by observations of nebulæ with the great telescope, and I have partially discussed it in *Himmel und Erde*, for June, 1889, page 503 *et seq.*

I proceed to give what seems to be the type curve of a certain family of spiral nebulæ. The accompanying Figure 2 shows several representations of a helix of wire, which I have found by trial to be capable of being projected into the shape of each one of the following nebulæ. Figure 2 also gives a scale photographed at the same time as the wire model. The diameter of the smallest circle of the scale is one inch, and the circles are successively $\frac{1}{10}$ of an inch greater in diameter. One inch is also marked near each of the vertical projections.

I give in Figure 3 a selection from projections of the type-helix of Figure 2, which were made by placing the wire model in a beam of parallel rays and tracing its shadow on a plane. Most of the comparisons of drawings of nebulæ with the type-helix have been made by placing the eye vertically over the plane of the paper and by moving the wire helix (its origin nearly always touching the paper in the nucleus of the nebula) until the projection of the helix accurately covered the drawing of the nebula. Usually the model must be applied n different times for a nebula with n branches. I have found no case in which this helix will fit one branch of a nebula without fitting every other branch also.

I give in what follows a few comparisons of this type-helix with drawings of nebulæ, and I begin with the admirable series of drawings given by MR. LASSELL in *Mem.* R. A. S., vol. 36:

LASSELL'S FIGURE.	G. C. No.	REMARKS.
2	600	The outlines of this nebula have been exactly reproduced (in our Fig. 3, No. 1). [The axis of the type-helix is in position angle 280°, and altitude above paper 70° to 75°.]
3	604	Ditto (when Lassell's figure is reversed).
9	1511	Ditto. (Compare our Fig. 3, No. 3.)
12 (a)	1861	Ditto (in our Fig. 3, No. 6); (b) compare the last drawing of Fig. 2. The nucleus of the nebula is probably due to a crossing of two loops of the helix.
12 (b)	1861	The outlines can be reproduced. (Compare our Fig. 3, Nos. 13, 24, 25.)
15	2373	The loop and the following edge of LASSELL's drawing can be exactly reproduced. (Compare our Fig. 3, Nos. 15, 19.)
16	2838	The axis of the main curve of the drawing has been exactly reproduced. (Compare our Fig. 3, No. 20.)
17	2890	Both these figures have been accurately reproduced. Each branch is a projection of the type-helix. (Compare our Fig. 3, Nos. 11, 16, 17.) Inner spiral, position angle 120°, altitude of axis 80° to 85°; outer spiral, position angle 120°, altitude 80°. If we match the inner spiral and then revolve the type-helix, keeping its axis in the same plane, about 90° in the direction S W N E the outer spiral will be matched.
27	3572 M 15	All the principal branches have been accurately reproduced; one application of the type-helix for each branch. (Compare our Fig. 3, Nos. 1, 7, 11, 16, 17.) Inner spiral, P = 150°, Alt. 85° to 90°; outer spiral, P = 150°, Alt. = about 80°. Revolve type-helix nearly 180° from the position where it matches the outer spiral in the direction N W S E, and it will match the inner spiral.
28	3606	When this drawing is reversed the three branches can be exactly reproduced by three applications of the type-helix. (Compare our Fig. 3, Nos. 8, 14, 15, 19, 20.) Is the nucleus due to the crossing of two branches of the helix?
29	3614	When this is reversed its two branches can be reproduced by two applications of the type. (Compare our Fig. 3, Nos. 5, 6, etc.)
33	4403	(The Omega nebula.) The axes of the loop and of the straight following part can be exactly reproduced. (Compare our Fig. 3, No. 31.)

N. B.—Note that the position angle of the axis of the type-helix is the same for both spirals of G. C. 2890; and for both spirals of G. C. 3572.

COMPARISONS WITH LORD ROSSE'S DRAWINGS IN THE PHILOSOPHICAL TRANSACTIONS, 1861.

FIG.	G. C.	REMARKS.
9	888	*h.* 327. (Compare our No. 1. etc.)
10	532	*h.* 131. This can be accurately reproduced when it is reversed and its scale changed suitably.
13	2053	*h.* 689. Ditto.
15	2216-17	*h.* 765-6. (Compare our Nos. 2, 3, 4, 12, 13, 28, 31.)
16	2377	*h.* 857. (Compare our Nos. 1, 7, 11, 16, 17, etc.)
18	2670-1	*h.* 1052-3. (Compare our Nos. 2, 3, 12, etc.)
19	2680	*h.* 1061. Can be reproduced.
21	2870	*h.* 1196. (Compare our Nos. 3, 9 (reversed), 12, 29, 30, etc.)
23	3341-2	*h.* 1306-8. (Compare our Nos. 5, 6, 21, etc., and 11, etc.)
24	3085	*h.* 1337. (Compare Nos. 2, 14, twice applied.)
25	3151	*h.* 1385. (Compare our Nos. 23, 24; and notice the opening on the lower side of the figure (as in Fig. 23) and the brightening of the nebula just above this (as in Fig. 23) where the right-hand hook bends back.)
26	3189-90	*h.* 1414-15. (Compare our Nos. 5, 6, 21, 29, 30.)
28	3511	*h.* 1589. (Compare our Nos. 5, 6, etc.)
29	3615	*h.* 1650. (Compare our No. 11, reversed.)
32	4160	*h.* 1946. (Compare our No. 1, etc.)
36	4594	*h.* 2084. If this drawing be reversed, each of the four branches can be accurately represented by projections of the type-helix. I have made a wire model of this nebula.*
41	4971	*h.* 2245. (Compare our No. 1, etc., reversed.)

* Before the present investigation was begun I succeeded in making a model of this nebula of four branches, starting on the assumption that each of the four branches was produced by the projection (at four different angles) of one and the same curve in space. I finally succeeded in bending a wire so that when it was held in four different positions (the origin of the helix always touching the nucleus), the four projections accurately covered the four branches as they are laid down in the drawing. I then laid this model to one side and constructed a type curve from the nebulæ G. C. 600, the great Nebula G. C. 3572 (M. 51) and others. This second type curve was then applied (reversed) to the nebula 4594, and it was found to accurately represent it, and to be the same curve as the one first constructed. Probably in this case, as in others, the conviction that the real type of the nebula has been discovered is more strongly brought home to the person who has actually constructed the models and found them to exactly represent the pictures, than to one who merely reads an account of how the experiment was conducted. The only ambiguity in my model of this nebula is due to the fact that it is impossible to decide on which side of the plane of projection any or all of the branches are situated. We know the real shape of each branch, but we do not know whether it lies on the hither or on the farther side of the plane of projection.

COMPARISON WITH LORD ROSSE'S DRAWINGS IN THE SCIENTIFIC TRANSACTIONS ROYAL DUBLIN SOCIETY, VOL. II.

PLATES.	G. C.	REMARKS.
I.	1202	(Compare our Figs. 24, 25)??
I.	1267	(Compare our Figs. 14, 15, 19, etc., reversed.)
I.	1519	This can be accurately reproduced.
II.	1520	Ditto.
III.	1861–3	The principal curves in these nebulæ, ditto.
IV.	3572	Ditto.
V.	4561	(Compare our Figs. 9, 10, the middle parts only.)
VI.	4403	The axes of this can be accurately reproduced. (See our Fig. 31.)

It is unnecessary to give more examples. Indeed, the cases already given include nearly all the spiral nebulæ. Those just referred to are sufficient to exhibit the whole evidence to any one who will construct for himself a type curve from the data in Figure 2, and who will go over the comparisons with the plates as above outlined. The spirals of *Nebula Orionis* are probably of the type just given, also. The case of the *Omega* nebula (G C. 4403) is very striking. I have also found remarkable analogies in various spiral streams of stars.

It may be objected to the suggestions given above that the forms of the nebulæ are so indefinite that a very great latitude is allowed in matching the drawings with the projections of any particular type curve. This is undoubtedly true. The only remedy for it is to obtain better representations of the nebulæ themselves by photographic means.

A second objection is that Figure 3 shows that a particular spiral, once assumed, may be projected into many forms, and that these might be sufficiently varied to be fitted to a comparatively small number of objects out of the many thousands of known nebulæ. To this it may be said that it is undoubtedly true that the projection of many different curves can be made to fit a certain number of the drawings referred to. Still, it appears to me, after trials, that the helix of Figure 2 comes nearer to being the type curve of the nebulæ in question than any other that I can now construct. It certainly will need to be corrected, but it seems to be a good first approximation.

The difficulty of improving it can be best appreciated by making the trial.

Again, it must be remembered that while there are many thousands of nebulæ, there are only comparatively few spiral nebulæ, and that the type curve fits a very great percentage of these, while it cannot be tortured into a resemblance to other nebulæ not spiral.

If the helix given in Figure 2 is indeed the type of a certain class of nebulæ, many interesting questions may receive a solution. For example, what are the directions in space of the *axes* of these different nebulæ? Is there anything systematic in these directions? What is the law of the force by which particles of matter are expelled from (or attracted to?) the central nucleus? Have we here in the nebulæ different types of spirals somewhat analogous to the different types of comets' tails so ably discussed by Professor BREDICHIN?

Some of the parts of these nebulæ must be approaching the earth, some receding from it. Can we by the spectroscope discriminate between such motions?

A suggestion which holds out even the hope of successfully attacking such problems is not without its value, and I have, therefore, no hesitation in presenting the foregoing paper in its present incomplete form.

EDWARD S. HOLDEN.

LICK OBSERVATORY, July 12, 1889.

ON THE ORBIT OF COMET BARNARD (1889, JUNE 23).

BY A. O. LEUSCHNER.

From Mr. BARNARD'S observations of June 23, 24, 25, I have deduced the following elements:

$$T = 1889, \text{ June } 20.1480 \text{ G. m. t.}$$

$$\left.\begin{aligned} \Omega &= 271^\circ\ \ 4'.1 \\ \omega &= 59^\circ 20'.7 \\ i &= 31^\circ 14'.6 \end{aligned}\right\} 1889.0$$

$$\log q = 0.04236$$

Obsd.—Computed; $\Delta\lambda \cos\beta = -0'.3$, $\Delta\beta = 0'.0$.

[ABSTRACT.]

ON THE OCCULTATIONS OF JUPITER (VISIBLE IN 1889); AND ON THE ECLIPSES OF SATELLITE IV.

By CHARLES B. HILL.

Mr. HILL spoke of the various phenomena of *Jupiter's* satellites, etc., of special interest, and called the attention of members especially to

The Eclipse (reappearance) of Satellite IV:

1889, August 18, at 8h. 37m., P. s. t.; and to

The Occultation of Jupiter by the Moon:

1889, Sept. 3—*Immersion,*	I	contact,	5h. 32.5m.,	P. s. t.
	II	"	5h. 34.5m.,	"
Emersion,	III	"	6h. 26.0m.,	"
	IV	"	6h. 28.0m.,	"

Angle from North Point, Imm. = 149°
" " " " Emer. = 234°

The above prediction is based on an approximate (graphical) computation for the position of Mt. Hamilton. The occultation will be visible in the United States generally. In California it will take place shortly before sunset, the moon being one day past *First Quarter.*

[ABSTRACT.]

ON PHOTOGRAPHING THE CORONA IN FULL SUNSHINE; AND ON PHOTOGRAPHS OF THE MOON IN THE DAYTIME.

By J. E. KEELER.

Mr. KEELER gave a brief account of the attempts that had been made to see and to photograph the corona in full sunshine, and spoke of the evidence of the eclipse photographs on the practicability of the latter experiment. It had been shown by Professor HOLDEN in the Eclipse Report of 1889 that if the intrinsic brilliancy of the daylight near the sun was 1000, the intrinsic brilliancy of the day-

light *plus* corona was not above 1002. Hence, to photograph the corona in full sunshine, we must be able to record a difference of brilliancy, a contrast, of $\frac{1}{500}$. The eye could detect a contrast of $\frac{1}{40}$ only, and hence the attempt seemed hopeless, as the rays and streamers of the corona had a continuous spectrum like that of diffused daylight. He also exhibited some photographs of the moon taken in the daytime by Mr. BURNHAM, with a lens of aperture = $\frac{3}{4}$ inch, focus = 9 inches, stop f/44, time $\frac{1}{60}$ to $\frac{1}{100}$ of a second. The moon was more than 120° from the sun at the time.

Experiments on this matter were recommended to the amateur photographers of the Society, and it was asked that successful trials might be communicated to the Lick Observatory. Photographs of the dark side of the moon before first quarter might be included in the plan. Each plate exposed should be marked with the observer's name; the aperture, stop, and plate employed; the hour and minute of exposure; the length of exposure.

Mr. KEELER exhibited some prints made on ordinary dry plates and on ortho-chromatic plates, and recommended the attention of the members of the Society to the excellent results attained by the use of the latter plates, and suggested a trial of them for pictures of the moon in the daytime, as the moon was relatively rich in light of greater wave length than F.

NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

The desire is expressed, on many sides, that the Publications of the Society should contain brief notices of the work current at the Lick Observatory, because much of this work is necessarily published in Eastern and foreign journals and therefore may escape the attention of our members.

Such notices must evidently be of the briefest and most popular character, and very often can be nothing more than a reference to the title and place of publication of a paper. Even such references as these may serve, it is said, to call the attention of our members to the existence of a paper which may be of interest to several of them.

It is therefore proposed, as an experiment merely, to include in

each of our Publications a few pages of items relating to the work of the Lick Observatory. Should these meet the want which has been expressed, it will be easy to continue them in the future. In this way an acquaintance with the work of the Observatory can be maintained, without taking too much space in the pages of our Publications, which should be reserved for longer articles by the members of the Society in general.

As the Observatory commenced active operations not long before the foundation of the Society, the present number of the *Notices* may well be devoted to a list of the mere titles of the different papers, etc., which have been sent to various scientific journals and magazines since June 1, 1888, by the members of the Observatory staff. Articles printed in newspapers, etc., are not included, as these are generally of transient interest only. This list, then, will bring the history of the astronomical activity of the Observatory up to the present time, and leave a clear field for the subsequent numbers of these *Notices*. E. S. H.

Photograph of the Davidson Comet.

The comet discovered by Mr. Davidson at Queensland, on July 21, was photographed at the Observatory by Mr. Barnard, with the new Willard lens (about 5 inches aperture, 30 inches focus) on July 30. A Seed 26 plate was used, and an exposure of ninety minutes was given. The camera was mounted on the top of the twelve-inch equatorial, and the camera was kept directed at the comet by moving the slow motion screws in R. A. and in Dec. As the comet had a rapid motion in reference to the stars, the latter appeared as *trails* about 13′ to 14′ long. This was the comet's motion in ninety minutes of time. The head of the comet shows as a neat round mass. The tail is fan-shaped, with its borders convex to the axis, and very narrow at the root. It can easily be traced 20′ and it is evident for about 53′. Mr. Barnard could trace it no further than 50′ or so, with the telescope. After the picture of the comet was taken, the negative was exposed to the light of our standard lamp for 1, 5, 10, 15, 20, 25 and 30 seconds, making a series of squares of standard intensity. (See Lick Observatory Eclipse Report, page 12.) The night-sky was less intense than the square exposed one second. The brightest part of the tail of the comet 2′ or so from the head matched the standard square exposed ten seconds. Hence the comet is about nine and one-half times as bright as its back-

ground. Omitting any consideration of the absorption of the atmosphere, and of the absorption of the lens (as yet undetermined), I find that the intrinsic brilliancy of this portion of the comet was 0.000,000,15 units of the standard lamp. The full moon has an intrinsic brilliancy of 1.66 units (PICKERING) and the brightest parts of the corona of January 1, 1889, had an intrinsic brilliancy of 0.08 units. Hence the comet is 10,000,000 times fainter than the full moon, area for area; and 500,000 times fainter than the brightest parts of the corona of last January. According to Mr. PICKERING's measures, the intrinsic brilliancy (actinic) of the sky within 5° from the full moon is 0.000,064 units; and thus the sky near the moon is 400 times brighter than the comet, and more than 4000 times as bright as the night-sky. These measures relate only to the photographic brilliancy of the comet. The visual brilliancy would be much higher relatively, as the observations of Mr. KEELER show the most refrangible end of its spectrum to be very weak.

The results just given are interesting and important in themselves, and they also have an historical value; since this is the first occasion on which the light of a comet has been actually measured with accuracy.*

The preceding experiment also suggests various applications. For example: we may measure the total amount of a comet's light on various dates, and compare this measured light with the amount of light reflected to us by the comet from the sun, which latter quantity can be accurately calculated. Thus, we might find

	JAN. 1.	JAN. 2.	JAN. 3, ETC.
Measured light from the comet	= L,	= M,	= N, etc.
Calculated light from the comet	= A,	= B,	= C, etc.
∴ Native light of the comet	= L - A,	= M - B,	= N - C, etc.

It has long been known that the brilliancy of comets increases beyond the theoretical amount as they approach the sun, owing to native light emitted by them under the influence of the sun. It appears that there is now some hope of tracing such changes of brilliancy from day to day, by photographic means, and of obtaining in this way some clue to the energy of the forces which produce these observed changes. E. S. H.

1889, July 31.

* Since the above was written, I have seen a reference to a measure of the light of the comet of 1881 [illegible] by JANSSEN (*Ann. Bureau Long.* 1882, p. 781), which is stated as 300,000 times fainter than the full moon. This book is not accessible to me, and I do not know if the brilliancy was measured, or only inferred from the time of exposure compared with that of the moon.

Spectrum of Davidson's Comet.

The spectrum of Davidson's comet was observed here with the twelve-inch equatorial, on July 31st, and with the thirty-six-inch equatorial, on August 1st. The *coma* showed a spectrum consisting of three somewhat diffuse bright bands, which were found to be identical in position with the carbon fluting given by the blue flame of a spirit lamp. A faint luminosity connected the bands, so that the spaces between them were not perfectly dark.

The nucleus gave a continuous spectrum not extending below the D line, with slight brightenings at the positions of the carbon flutings. Such a spectrum would probably be given by the material of the *coma* at an increased pressure. Although the comet is now rated at about the sixth magnitude, its spectrum is much fainter than that of a star of this brightness, on account of the diffusion of its light over a large area. J. E. K.

Aug. 2, 1889.

New Double Stars.

One of the more recent double-star discoveries with the thirty-six-inch telescope is a seventh-magnitude star (D. M. 30°, 4809) near η Pegasi. The measures on three nights give:

1889.55	335°.3	0″.23	7.2	8.2

The 4-5 m. star, ψ *Cassiopeæ*, has been known since the first Herschel as a triple star, from a small double companion at a distance of 28″ from the large star. The Lick telescope shows a small star of about 13-5 m. at a distance of 3″.2 in the direction of 41°.2.

A careful set of measures of the close pair, κ *Pegasi* (β 989) has been made with the thirty-six-inch telescope. The change in both angle and distance has been very great since its discovery with the Chicago telescope in 1880. As the distance now is only 0″.14, it could hardly be seen, or measured, with any instrument much smaller than the Lick telescope. The components differ by only about half a magnitude, and there is a possibility of the wrong quadrant having been given in my first measures made in 1880, although at the time this was carefully looked after. Taking the early measures as they stand, the motion (direct) would be 235° in nine years. If the first angle should be reversed, the change would be only 56°.

There is a small star 11″ distant, which makes the double, Σ 2824. This is fixed with reference to the bright star.

28 *Andromedæ* is also a new double star. The following is the mean of three nights' measures with the thirty-six-inch refractor:

1889.51	360°.1	2″.42	5.5	13.3

HERSCHEL, at the Cape of Good Hope, noted a small double star in the fine cluster and nebula, MESSIER 8, and entered it as No. 5009 of the Cape Catalogue. The Lick telescope shows that the principal star of HERSCHEL's pair is a close pair. The mean of four measures is:—

1889.40	55°.6	0″.63	8.7	9.5

There is probably no change in HERSCHEL's more distant star.

	°	″			
1837.70	20.8	2.	10.	12.	1n H
1880.58	19.9	3.86	9.0	9.5	1n Cin
1889.40	23.3	4.05	8.7	9.6	4n β

For many years Σ 2438 has been found to be single with all telescopes. A recent set of measures with the large refractor of the Lick Observatory gives for the distance 0″.24, and the position angle 46°.2. The angle when measured by STRUVE in 1832 was 340°.6.

With powers up to 2000, the thirty-six-inch shows the large star of Σ 3130 as single. It has not been seen double during the last thirty years. S. W. B.

MERIDIAN CIRCLE OBSERVATIONS OF *VICTORIA* AND COMPARISON STARS.

In connection with astronomers in the northern hemisphere, the Astronomer Royal at the Cape of Good Hope, Dr. DAVID GILL, is observing the planet *Victoria*, for the determination of its parallax (and hence of the Solar Parallax). He has requested various observatories to determine, by meridian observations, the positions of the planet and of thirty-seven comparison stars. This work has been done at the Lick Observatory by eighteen nights of observations, between June 8 and July 8, and the results will soon be ready for publication. From a series of experiments, it was found that (thanks to the designer of the large pivots, nearly four inches in diameter) much better results could be obtained when the observations were made without clamping the instrument. The clamp was accordingly removed (some months ago), so that all of the observations referred to above were made with the nearly counterpoised instrument hanging freely in the wyes. That this variation from the usual method is to be approved, when the proper precautions are taken, seems to be shown by the smallness of the probable errors of observation, which,

for a single observation in R. A. and Dec., are about 0ˢ.020 and 0″.25 respectively. These figures also show that the REPSOLD meridian circle is capable of first-class work, and that the refraction as given in Vol. 1, *Publications Lick Observatory*, is not very far out of the way. J. M. S.

NEW DOUBLE STARS.

I have found the stars, 2 *Piscium* and W XXIII.803 to be double with the twelve-inch equatorial. Mr. BURNHAM has kindly measured these stars with the thirty-six-inch and supplied me with his results for publication. From the inequality of the components, 2 *Piscium* is a difficult object with the twelve-inch.

Following are Mr. BURNHAM'S measures. E. E. B.

1889, August 5.

2 Piscium.

22h. 53m. 18s. }
0° 19′ }

	°	″		
1889.553	96.0	3.87	6	14
.556	91.8	3.88	6	13.5
.589	93.1	3.68	6	13.5
1889.57	93.6	3.81	6	13.7

W XXIII.803.

23h. 40m. 53s. }
4° 35′ }

	°	″		
1889.553	166.2	0.49	8.7	8.7
.556	166.5	0.59	8.6	8.6
.589	166.0	0.53	8.5	8.5
1889.57	166.2	0.54	8.6	8.6

LIST OF THE ARTICLES, ETC., CONTRIBUTED TO SCIENTIFIC AND OTHER JOURNALS BY THE ASTRONOMERS OF THE LICK OBSERVATORY SINCE JUNE 1, 1888.

[COMPILED BY MR. C. B. HILL.]

Writings of Edward S. Holden.

Hand-Book of the Lick Observatory. San Francisco, June, 1888. 32°, pp. 135.

Stellar Photography.—*Overland Monthly*, June, 1888.

Note on Earthquake Intensity in San Francisco, 1808-1888.—*American Journal of Science*, June, 1888.

The Total Solar Eclipse of 1889, January 1st, in California.—*Monthly Notices Royal Astronomical Society*, vol. 48.

Occultation of 47 Libræ by Jupiter, June 9, 1888.—*Astronomical Journal*, vol. 8, p. 64.

The Ring Nebula in Lyra.—*Monthly Notices Royal Astronomical Society*, vol. 48, p. 383.

Regarding Sir W. Herschel's observations of Volcanoes in the Moon. *The Observatory*, 1888, p. 334.

Earthquakes in California, Washington and Oregon, 1769-1888. Communicated to the *California Academy of Sciences* in July, 1888.

Sidereal Astronomy, Old and New. 2 papers.—*The Century* for August and September, 1888.

Occultation of a Star (11th magnitude) by Mars.—*Astronomical Journal*, vol. 8, p. 102.

Observations of the Lunar Eclipse of July 22, 1888, at the Lick Observatory of the University of California. Communicated to the *National Academy of Sciences.* [By all the astronomers].

Suggestions for Observing the Total Eclipse of the Sun on January 1, 1889. (Printed by Authority of the Regents of the University of California). State Printing Office, Sacramento, 1888. 8vo, pamphlet.

Hypothetical Parallax of Binary Pairs.—*Sidereal Messenger*, October, 1888, p. 356.

Physical Observations of Mars during the Opposition of 1888, at the Lick Observatory. (With a plate).—*Astronomical Journal*, vol. 8, p. 97.

The Same.—*Journal of Liverpool Astronomical Society*, vol. 7, November, 1888, p. 7, with plates.

Saturn and his Satellites.—*Sidereal Messenger*, January, 1889.

Observations of Nebulæ at the Lick Observatory (by E. S. Holden and J. M. Schaeberle).—*Monthly Notices Royal Astronomical Society*, vol. 48 (1888) p. 388.

The Lick Observatory.—*The Universal Review* (London), February 15, 1889, (illustrated).

Earthquakes in California (1888).—*American Journal of Science*, May, 1889, p. 392.

On the Solar Eclipse of January 1, 1889.—*Observatory*, March, 1889, page 130; May, p, 221.

The Lick Observatory.—*Himmel und Erde* (Berlin; illustrated), May and June, 1889.

On the Photographs of the Corona at the Solar Eclipse of January, 1, 1889.—*Monthly Notices Royal Astronomical Society*, vol. 49, p. 343.

Reported Changes in the Rings of Saturn. (Observations by E. S. Holden, J. M. Schaeberle, J. E. Keeler, E. E. Barnard.)—*Astronomical Journal*, vol. 8, p. 180.

Occultation of the Planet Jupiter, as observed at the Lick Observatory, March 23, 1889. (Observations by J. E. Keeler, E. E. Barnard, C. B. Hill, A. O. Leuschner.)—*Sidereal Messenger*, May, 1889, p. 221.

Address before the Astronomical Society of the Pacific "On the Work of an Astronomical Society."—*Publications Astronomical Society of the Pacific*, No. 2, March 30, 1889.

Reports on the Observations of the Total Solar Eclipse of January 1, 1889. Published by the Lick Observatory, 8vo.

Great Telescopes and their Work.—*Observatory*, March, 1889, p. 138.

Recent Discoveries in the Nebulæ by means of Photography.—*Scientific American*, July 27, 1889.

On the Helical Nebulæ.—*Publications Astronomical Society of the Pacific*, No. 3, July 27, 1889. Die Helikalischen Nebel.—*Himmel und Erde.*

Astronomical Photography.—*The Pacific Review*, September, 1889.

Writings of S. W. Burnham.

Double Star Observations made at the Lick Observatory.—*Astronomische Nachrichten*, No. 2875.

New Double Stars Discovered at the Lick Observatory.—*Astronomical Journal*, vol. 8, p. 141.

Companion to Sirius.—*Astronomische Nachrichten*, No. 2884.

The Trapezium of Orion.—*Monthly Notices Royal Astronomical Society*, 1889, vol. 49, p. 352.

The Double Star, ε Hydræ.—*Sidereal Messenger*, May, 1889.

New Double Star, α Ursæ Majoris.—*Astronomische Nachrichten*, No. 2891.

Seventeen Comæ Berenices.—*Observatory*, May, 1889, p. 227.

Double Star Observations made with the 36-inch refractor of the Lick Observatory.—*Astronomische Nachrichten*, No. —.

η Ophiuchi, θ Cygni.—*Astronomische Nachrichten*, No. 2912.

Writings of J. M. Schaeberle.

Elements and Ephemeris of Barnard's Comet (e), 1888.—*Astronomical Journal*, vol. 8, p. 102; *Sidereal Messenger*, October, 1888, p. 357. Communicated to the *California Academy of Sciences.*

Orbit and Proper Motion of 85 Pegasi (β 733).—*Astronomical Journal*, vol. 8, p. 129. Communicated to the *California Academy of Sciences.*

Elements and Ephemeris of Barnard's Comet (f), 1888.—*Astronomical Journal*, vol, 8, p. 144; *Sidereal Messenger*, December, 1888. Communicated to the *California Academy of Sciences.*

Observations of Nebulæ at the Lick Observatory (by E. S. Holden and J. M. Schaeberle).—*Monthly Notices Royal Astronomical Society*, vol. 48 (1888), p. 388.

Meridian Observations of Polyhymnia and Harmonia.—*Astronomische Nachrichten*, No. 2877.

Corrections to the Lick Observatory Time Signals for December 30.0, December 31.0, January 1.0, and January 2.0.—*Astronomical Journal*, vol. 8, p. 168.

Elements and Ephemeris of Barnard's Comet (March 31). Communicated to the *California Academy of Sciences*; telegraphed to *Astronomical Journal*, and printed in vol. 8, pp. 183 and 191; *Astronomische Nachrichten*, No. 2839. See also *Astronomische Nachrichten*, No. 2903.

Reports on the Solar Eclipse of January 1, 1889.—In *Lick Observatory Reports*, p. 23.

Writings of J. E. Keeler.

The 36-inch Equatorial of the Lick Observatory.—*Scientific American*, June 16, 1888.

Recent Astronomical Work at the Lick Observatory.—*Scientific American*, November 10, 1888.

Observations of the Satellites of Mars.—*Astronomical Journal*, No. 178, pp. 73-78.

The Appearance of Saturn in the 36-inch Equatorial of the Lick Observatory.—*Ciel et Terre*, No. 21, January, 1889, p. 514.

The Outer Ring of Saturn.—*Ciel et Terre*, No. 3, April, 1889. *Astronomical Journal*, vol. 8, p. 175.

Report on the Total Solar Eclipse of January 1, 1889.—In the *Lick Observatory Report*, p. 31.

On the Spectra of Saturn and Uranus.—*Astronomische Nachrichten*, No. —.

Writings of E. E. Barnard.

Discovery and Observations of a Comet (e 1888).—*Astronomical Journal*, vol. 8, p. 102; *Astronomische Nachrichten*, No. 2862.

Drawings of Comet, 1888, I.—*Astronomische Nachrichten*, No. 2859. (With a plate.)

Discovery of a Comet (f, 1888).—*Astronomical Journal*, vol. 8, p. 128. Communicated to *California Academy of Sciences*.

Observations of Olbers' Comet (1887, V).—*Astronomische Nachrichten*, No. 2861.

Discovery and Observations of a Comet (f, 1888).—*Astronomische Nachrichten*, No. 2871, p. 237; *Astronomical Journal*, vol. 8, p. 134.

Note on the Orbit of Comet (e), 1888.—*Astronomical Journal*, vol. 8, p. 120.

On a Search for the Comet reported January 15, 1889, by MR. BROOKS. —*Astronomical Journal*, vol. 8, p. 168.

Partial Eclipse of the Moon, January 16, 1889.—*Sidereal Messenger*, March 1889, p 137.

Discovery and Observations of Comet Barnard (March 31).—*Astronomical Journal*, vol. 8, p. 183; *Astronomische Nachrichten*, No. 2894; *Astronomical Journal*, vol. 9, p. 5; *Astronomische Nachrichten*, No. 2899; *Astronomische Nachrichten*, No. 2901.

Report on the Total Eclipse of January 1, 1889.—In the *Lick Observatory Report*, p. 56.

Observations of Faye's Comet.—*Astronomische Nachrichten*, No. —; *Astronomical Journal*, vol. 9, p. 29.

Anomalous Tail of Comet I, 1889.—*Astronomical Journal*, vol. 9, p. 32; *Astronomische Nachrichten*, No. 2906.

The Nebula G. C. 2091.—*Monthly Notices Royal Astronomical Society*, vol. 49, p. 418.

The Cluster G. C. 1420, and the Nebula N. G. C. 2237. *Astronomische Nachrichten*, No. —.

Discovery and Observations of a Comet (June 23).—*Astronomische Nachrichten*, No. 2906; *Astronomical Journal*, vol. 9, p. 47.

Writings of C. B. Hill.

Observations of Comet, 1888, I.—*Astronomische Nachrichten*, No. 2877.

Report on the Total Solar Eclipse of January 1, 1889.—In *Lick Observatory Report*, p. 74.

Writings of A. O. Leuschner.

Bahn des Cometen Barnard (Marz 31) aus Beobachtungen mit eintaegigen Zwischenzeiten nach v. Oppolzer's Methode.—*Astronomische Nachrichten*, No. 2907.

Reports on the Total Eclipse of January 1, 1889 —In the *Lick Observatory Report*, p. 81.

Orbit of Comet Barnard (1889, June 23).—*Astronomische Nachrichten*, No. 2909; *Astronomical Journal*, vol. 9, p. 40; *Publications of the Astronomical Society of the Pacific*, No. 3.

Minutes of the Meeting of the Board of Directors, held July 27, 1889, at the Lick Observatory.

A quorum was present.

The Committee on the Diploma was authorized to expend not to exceed $50.

It was *Resolved*, That the Publications of the Astronomical Society of the Pacific be regularly sent to the following Observatories, etc., and that the Secretaries of the Society be instructed to notify them of this resolution, and to request that they exchange their publications with our own; and that the list of these Corresponding Societies and Observatories be printed in the Publications of the Astronomical Society of the Pacific:

Dudley Observatory, Albany, New York.
Detroit Observatory, Ann Arbor, Michigan.
Royal Observatory, Berlin, Germany.
University Observatory, Bonn, Germany.
Royal Observatory, Brussels, Belgium.
University Observatory, Cambridge, England.
Harvard College Observatory, Cambridge, Massachusetts.
Royal Observatory, Capetown, Africa.
University Observatory, Cincinnati, Ohio.
University Observatory, Dorpat, Russia.
Royal Observatory, Greenwich, England.
Ducal Observatory, Karlsrühe, Germany.
University Observatory, Kasan, Russia.
University Observatory, Koenigsberg, Prussia.
Royal Observatory, Kopenhagen, Denmark.
University Observatory, Leiden, Holland.
University Observatory, Leipzig, Germany.
Royal Observatory, Milan, Italy.
Observatory, Melbourne, Australia.
University Observatory, Moscow, Russia.
Lick Observatory, Mount Hamilton, California.
Royal Observatory, Munich, Germany.
Carleton College Observatory, Northfield, Minnesota.
Radcliffe Observatory, Oxford, England.
Savilian Observatory, Oxford, England.
National Observatory, Paris, France.
Astrophysikalishes Institut, Potsdam, Germany.
Imperial Observatory, Pulkowa, Russia.
Observatory of the Roman College, Rome, Italy.
University Observatory, Stockholm, Sweden.
University Observatory, Strassburg, Germany.
McCormick Observatory, University of Virginia, Virginia.
Naval Observatory, Washington, District of Columbia.
Imperial Observatory, Vienna, Austro-Hungary.
Royal Astronomical Society, London, England.
Liverpool Astronomical Society, Liverpool, England.
Astronomical Society of France, Paris, France.
Astronomical Society, Chicago, Illinois.
Astronomical Society of Germany, Leipzig, Germany.
Gesellschaft Urania, Berlin, Germany.
National Academy of Sciences, Washington, District of Columbia.
Smithsonian Institution, Washington, District of Columbia.
California Academy of Sciences, San Francisco, California.
Bureau des Longitudes, Paris, France.
The Nautical Almanac, London, England.
The American Ephemeris, Washington, District of Columbia.
Berliner Jahrbuch, Berlin, Germany.
Library of the Mechanics Institute, San Francisco, California.
Library of Congress, Washington, District of Columbia.
Mercantile Library, San Francisco, California.

Library of the University of California, Berkeley, California.
Chabot Observatory, Oakland, California.
Royal Observatory, Edinburgh, Scotland.
University Observatory, Cambridge, England.
Observatory, Nice, France.
Observatory, Marseilles, France.
Observatory, Bordeaux, France.
Observatory, Lyons, France.
Observatory, Toulouse, France.
Observatory, Kiel, Germany.
Observatory, Gotha, Germany.
Observatory, Hamburg, Germany.
Observatory of Geneva, Switzerland.
Observatory of Zurich, Switzerland.
Observatory of Berne, Switzerland.
Observatory of Neuchâtel, Switzerland.
Observatory of Madrid, Spain.
Observatory of Lisbon, Portugal.
Observatory of Naples, Italy.
Observatory of Palermo, Italy.
Observatory of Upsala, Sweden.
Observatory of Lund, Sweden.
Observatory of Christiania, Sweden.
Observatory of Helsingfors, Russia.
Observatory of Tacubaya, Mexico.
Observatory of Cordoba, Argentine Republic.
Observatory of Rio Janeiro, Brazil.
Observatory of Santiago, Chile.
Observatory of Madras, India.
Observatory of Sydney, New South Wales.
Observatory of Amherst College, Massachusetts.
Observatory of Clinton, New York.
Observatory of Georgetown, District of Columbia.
Observatory of Glasgow, Missouri.
Observatory of Hanover, New Hampshire.
Washburn Observatory, Madison, Wisconsin.
Winchester Observatory, New Haven, Connecticut.
Halstead Observatory, Princeton, New Jersey.
La Plata Observatory, La Plata, Argentine Republic.
Williams College Observatory, Williamstown, Massachusetts.
University Observatory, Tokio, Japan.

Mr. HOLDEN presented to the Board of Directors a communication from Hon. JOSEPH A. DONOHOE, of Menlo Park, relating to the establishment of a comet medal, and it was

Resolved, That the Board of Directors recommends to the Society the acceptance of Mr. DONOHOE's generous gift.

Resolved, That on the acceptance of the gift by the Society, Mr. DONOHOE's name be placed on the roll of Life-Members; that the *Donohoe Fund for the maintenance of the Comet Medal of the Astronomical Society of the Pacific* be placed under the immediate charge of the Finance Committee; and that the Committee on the Comet Medal shall, until the next annual meeting, or until their successors are appointed, be composed as follows:

The Director of the Lick Observatory, *ex officio*, and of Messrs. SCHAEBERLE and BURCKHALTER on the part of the Society.

It was *Resolved*, That Article VII of the By-Laws of the Astronomical Society of the Pacific be amended so as to read as follows:

"ARTICLE VII.

"Candidates for membership may be proposed at any meeting of the Society and may be elected at the same meeting by unanimous consent of those present. In case of dissent of any one member, candidates so proposed shall be voted for at the next succeeding meeting. The vote shall be by ballot, and a majority of the members present shall be required for an election."

This was adopted by the consenting votes of nine members of the Board of Directors, namely: Messrs. ALVORD, BURCKHALTER, GIBBS, GRANT, HOLDEN, LOWDEN, MOLERA, PIERSON, SCHAEBERLE, and therefore takes the place of Article VII in the By-Laws as printed in Publications No. 1.

The printing of Publications No. 3 and the preparation of photo-lithographic plates to illustrate it and Publications No. 4, was ordered.

The life members whose names are marked with a star (*) in the list of members given in full in the minutes of the meeting of the Society July 27, were duly elected by the Board of Directors. Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD JULY 27, 1889, AT THE LICK OBSERVATORY.

[PREPARED BY THE SECRETARIES FOR PUBLICATION.]

The minutes of the meeting of May 25, 1889, were read and approved.

Sixty-five persons were elected to membership under the provisions of the newly adopted Article VII of the By-Laws. For the convenience of the Society a full list of its present members is given below. This list includes the members elected at the present meeting. All are active members, except those whose names are marked with a star (*), to signify that they have been elected to life-membership.

LIST OF MEMBERS, JULY 27, 1889.

NAME.	ADDRESS.
T. P. ANDREWS,	529 Commercial Street, San Francisco, Cal.
Hon. HENRY B. ALVORD,*	San Jose, Cal.
Hon. WM. ALVORD,*	Bank of California, San Francisco, Cal.
Mrs. WM. ALVORD,*	Palace Hotel, San Francisco, Cal.
Director ANGEL ANGUIANO,	National Observatory, Tacubaya, Mexico.
Dr. WM. BOERICKE,	834 Sutter Street, San Francisco, Cal.
S. W. BURNHAM,	Lick Observatory, Mt. Hamilton, Cal.
E. E. BARNARD,	Lick Observatory, Mt. Hamilton, Cal.
CHAS. BURCKHALTER,	Chabot Observatory, Oakland, Cal.
L. M. BIXLEY,	317 California Street, San Francisco, Cal.
JOHN C. BULLOCK,	1626 Twelfth Street, Oakland, Cal.
D. P. BELKNAP,	604 Merchant Street, San Francisco, Cal.
Hon. JOHN H. BOALT,	332 Haight Street, San Francisco, Cal.
H. F. COMPTON,	966 Chester Street, Oakland, Cal.
Col. C. F. CROCKER,	4th & Townsend Streets, San Francisco, Cal.
J. C. CEBRIAN,	Pine & Octavia Streets, San Francisco, Cal.
J. COSTA,	406 Montgomery Street, San Francisco, Cal.
E. BENTLEY CHURCH,	1036 Valencia Street, San Francisco, Cal.
CHAS. S. CUSHING,	1669 Thirteenth Street, Oakland, Cal.
Dr. J. CALLANDREAU,	1307 Stockton Street, San Francisco, Cal.
C. H. CLEMENT,	Livermore, Cal.
Dr. W. A. DEWEY,	834 Sutter Street, San Francisco, Cal.
L. L. DUNBAR, D. D. S.,	500 Sutter Street, San Francisco, Cal.
Hon. JOSEPH A. DONOHOE,*	Menlo Park, Cal.
EUGENE FROST,	Alameda, Cal.
ARTHUR W. FOSTER,*	322 Pine Street, San Francisco, Cal.
Hon. JAMES G. FAIR,*	230 Montgomery Street, San Francisco, Cal.
J. W. FENN,	319 California Street, San Francisco, Cal.
ANDREW B. FORBES,*	401 California Street, San Francisco, Cal.
ROBERT D. FRY,*	1812 Jackson Street, San Francisco, Cal.
CHAS. W. FRIEND,	Carson City, Nevada.
EDMUND GRAY,	2925 Jackson Street, San Francisco, Cal.
Dr. C. L. GODDARD,	131 Post Street, San Francisco, Cal.
CHASE GITCHELL,	609 Sacramento Street, San Francisco, Cal.
C. P. GRIMWOOD,	Fruitvale, Cal.

W. C. GIBBS, ...	303 California Street, San Francisco, Cal.
C. MITCHELL GRANT, ...	331 Kearny Street, San Francisco, Cal.
ADAM GRANT,*	Bush & Sansome Streets, San Francisco, Cal.
JOSEPH D. GRANT,*	Bush & Sansome Streets, San Francisco, Cal.
Capt. CHARLES GOODALL, ...	McAllister & Pierce Sts., San Francisco, Cal.
CAMILO GONZALEZ, ...	National Observatory, Tacubaya, Mexico.
Hon. J. M. GITCHELL, ...	609 Sacramento Street, San Francisco, Cal.
C. WEBB HOWARD,*	Pacific Union Club, San Francisco, Cal.
Prof. E. S. HOLDEN, ...	Lick Observatory, Mt. Hamilton, Cal.
C. B. HILL, ...	Lick Observatory, Mt. Hamilton, Cal.
WM. F. HERRICK, ...	439 California Street, San Francisco, Cal.
Dr. H. W. HARKNESS, ...	California Academy of Sciences, cor. California & Dupont Sts., San Francisco, Cal.
F. H. HAUSMAN, ...	328 Montgomery Street, San Francisco, Cal.
Judge S. G. HILLBORN, ...	401 California Street, San Francisco, Cal.
HORACE L. HILL, ...	314 California Street, San Francisco, Cal.
WM. IRELAND, ...	301 California Street, San Francisco, Cal.
J. R. JARBOE, ...	917 Pine Street, San Francisco, Cal.
P. R. JARBOE, ...	917 Pine Street, San Francisco, Cal.
E. B. JORDAN, ...	581 Market Street, San Francisco, Cal.
J. H. JOHNSON, ...	414 Buchanan Street, San Francisco, Cal.
JAMES G. JONES, ...	Room 61, Flood Building, San Francisco, Cal.
Hon. JOHN P. JONES,*	Gold Hill, Nevada.
Miss FIDELIA JEWETT, ...	San Francisco High School, San Francisco, Cal.
J. E. KEELER, ...	Lick Observatory, Mt. Hamilton, Cal.
HENRY KAHN, ...	212 Kearny Street, San Francisco, Cal.
O. V. LANGE, ...	1025 Market Street, San Francisco, Cal.
W. H. LOWDEN, ...	213 Sansome Street, San Francisco, Cal.
Prof. JOHN LE CONTE, ...	Berkeley, Cal.
A. O. LEUSCHNER, ...	Lick Observatory, Mt. Hamilton, Cal.
W. B. LEWITT, M. D., ...	Cor. Hayes & Laguna Streets, San Francisco, Cal.
JOSEPH G. LAVERY, ...	410 California Street, San Francisco, Cal.
Miss L. J. MARTIN, ...	San Francisco High School, San Francisco, Cal.
F. H. MCCONNELL, ...	618 Market Street, San Francisco, Cal.
E. J. MOLERA, ...	850 Van Ness Avenue, San Francisco, Cal.
C. F. MONTEALEGRE, ...	230 California Street, San Francisco, Cal.
ALEXANDER MONTGOMERY,* .	N. W. cor. Leavenworth & Vallejo Streets, San Francisco, Cal.
Mrs. ALEXANDER MONTGOMERY,*	N. W. cor. Leavenworth & Vallejo Streets, San Francisco, Cal.
Hon. J. W. MCCLYMONDS, ...	City Hall, Oakland, Cal.
Hon. D. O. MILLS, ...	224 Montgomery Street, San Francisco, Cal.
Rev. ROBERT MACKENZIE, . .	First Presbyterian Church, San Francisco, Cal.
Hon. WM. NORRIS, ...	927 Bush Street, San Francisco, Cal.
Miss ROSA O'HALLORAN, . . .	1511 Clay Street, San Francisco, Cal.
W. LETTS OLIVER, ...	1110 Twelfth Street, Oakland, Cal.
SAM. C. PARTRIDGE, ...	529 Commercial Street, San Francisco, Cal.
WM. M. PIERSON, ...	76 Nevada Block, San Francisco, Cal.
Hon. T. GUY PHELPS, ...	Belmont, Cal.
Dr. S. C. PASSAVANT, ...	306 Guerrero Street, San Francisco, Cal.
Hon. GEO. C. PERKINS,* . . .	Oakland, Cal.
JOHN PERRY, JR.	Occidental Hotel, San Francisco, Cal.
JOHN PARTRIDGE, ...	214 California Street, San Francisco, Cal.
Dr. GEO. C. PARDEE, ...	526 Montgomery Street, San Francisco, Cal.
Señor MANUEL G. PRIETO, . .	Tacubaya, Mexico.
LAWRENCE H. PIERSON, . . .	Pacific Pine Lumber Co., San Francisco, Cal.
FEODORO QUINTANO, ...	National Observatory, Tacubaya, Mexico.
ALFRED P. REDINGTON, . . .	53 Stevenson Street, San Francisco, Cal.

GEO. W. REED,	506 Battery Street, care W. B. Tyler, San Francisco, Cal.
E. W. RUNYON,	53 Stevenson Street, San Francisco, Cal.
V. J. A. REY,	829 Union Street, San Francisco, Cal.
A. W. ROSS, JR.	224 California Street, San Francisco, Cal.
Hon. ARTHUR RODGERS,	Nevada Block, San Francisco, Cal.
Rev. J. L. RICARD,	Santa Clara, Cal.
LESTER L. ROBINSON,*	320 Sansome Street, San Francisco, Cal.
FRANCISCO RODRIGUEZ REY,	National Observatory, Tacubaya, Mexico.
ALBERT RAYMOND,	76 Nevada Block, San Francisco, Cal.
J. M. SCHAEBERLE,	Lick Observatory, Mt. Hamilton, Cal.
Prof. I. STRINGHAM,	Berkeley, Cal.
Prof. F. SOULÉ,	Berkeley, Cal.
J. M. SELFRIDGE,	Oakland (Box 37), Cal.
JOHN R. SPRING,*	328 Montgomery Street, San Francisco, Cal.
GEORGE H. STRONG,	220 Market Street, San Francisco, Cal.
M. J. SULLIVAN, D. D. S.	30 Post Street, San Francisco, Cal.
A. J. TREAT,	224 McAllister Street, San Francisco, Cal.
W. B. TYLER,	506 Battery Street, San Francisco, Cal.
EDWARD G. THOMAS,	234 Montgomery Street, San Francisco, Cal.
C. W. TIEDEMAN,	312 Sixth Street, San Francisco, Cal.
Hon. ALFRED L. TUBBS,*	611 Front Street, San Francisco, Cal.
CHARLES R. TISDALE,	Alameda, Cal.
JACOB VOORSANGER,	2316 California Street, San Francisco, Cal.
RUDOLPH E. VOIGHT,	207 California Street, San Francisco, Cal.
Señor FELIPE VALLE,	National Observatory, Tacubaya, Mexico.
Prof. J. T. WALLACE,	Highland Park, Oakland, Cal.
R. H. WHITE,	1216 Haight Street, San Francisco, Cal.
J. C. L. WADSWORTH,	Pacific-Union Club, San Francisco, Cal.
CHARLES G. YALE,	220 Market Street, San Francisco, Cal.
F. R. ZIEL,	410 California Street, San Francisco, Cal.

The list of presents received was read by the Secretary, and the thanks of the Society were voted to the donors. It was reported from the Committee on the Diploma that a design was now preparing and would soon be ready for examination. Also that designs for the comet medal had been sought for.

The attention of the members of the Society was called to the volume recently published by Professor TACCHINI, in which he gives an account of his expeditions to observe the total solar eclipses of 1870, 1882, 1883, 1886 and 1887, together with many plates and illustrations. This volume has been prepared by Professor TACCHINI, in order that the proceeds of its sale might be devoted to the erection of a suitable monument to the noted Italian astronomer, Padre SECCHI. The work can be had through B. WESTERMANN & Co. (Box 2306, New York City), at a cost of about $2.

It was also *Resolved*, That the Astronomical Society of the Pacific will join with the Astronomers of the Lick Observatory in sending a telegram of greeting and congratulation to Director OTTO V. STRUVE, on August 19, 1889, the fiftieth anniversary of the founding of the Pulkowa Observatory and of Director STRUVE'S official connection with it.

A communication from the Hon. JOSEPH A. DONOHOE, of Menlo Park, was presented to the Society by Mr. HOLDEN. In this communication Mr. DONOHOE offers to establish a perpetual fund to provide for the bestowal of a medal of bronze upon the actual discoverer of each new comet according to the provisions hereafter given.

Mr. DONOHOE will provide the necessary dies for the medal, and will present to the Society ten finished medals, and also an invested fund of $500 to be known as the *Donohoe Fund for the Maintenance of the Comet Medal of the Astronomical Society of the Pacific.* The conditions of the gift follow :

COMET MEDAL OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC.

I. A medal of bronze is established as a perpetual foundation to be given for the discovery of comets as follows:

The medal is to bear on the obverse the effigy of a bright comet among stars, with the legend "*Astronomical Society of the Pacific*" around the border; and on the reverse the inscription "*This medal, founded in 1890 by Joseph A. Donohoe, is presented to* —— [the name of the discoverer] *to commemorate the discovery of a comet* —— [the date].

It is to be understood that this medal is intended solely as a recognition of merit, and not as a reward.

II. The medal will be given to the actual discoverer of any unexpected comet, when the discovery is made in the course of regular astronomical occupations; and to that observer of any telescopic periodic comet who obtains and promptly publishes the first precise determination of its position at any one of its expected returns.

III. The discoverer is to make his discovery known in the usual way; and he must also address a letter, giving his first observation, to the Director of the Lick Observatory, by the first mail after the discovery. This letter must state the exact time of the discovery, the position of the comet, the direction of its motion (when this can be determined), and the physical appearance of the object.

If the observations of one night are not sufficient to settle all these points, the discovery must nevertheless be communicated as prescribed, and a second letter can be sent, giving the missing items of information, when they are obtained. The expectation of obtaining a second observation will never be received as a reason for postponing the communication of the first one. No application for the bestowal of the medal is required. The letters received from discoverers of comets will be preserved in the records of the Lick Observatory. Cable telegrams to the Lick Observatory are to be addressed to "Astronomer, San Francisco."

IV. All such communications will be referred to a committee consisting of the Director of the Lick Observatory, *ex officio*, and of two other persons, members of the Astronomical Society of the Pacific, who are to be annually appointed by the Board of Directors. The decisions of this committee are to be final upon all points relating to the award of the medal. The committee will print an annual statement of its operations in the Publications of the Society.

Under ordinary circumstances the medal for the discovery of a

comet will be awarded within two months after the receipt of the letter of the discoverer which contains the record of his first observation. In cases of doubt a longer period may elapse. The medal will not be awarded (unless under the most exceptional circumstances) for the discovery of a comet until enough observations are secured (by the discoverer or by others) to permit the calculation and the verification of its orbit.

V. This medal is to be a perpetual foundation from and after January 1, 1890.

It was, on the recommendation of Board of Directors,

Resolved, That the Astronomical Society of the Pacific accepts the generous gift of Mr. DONOHOE under the conditions named by him, and

Resolved, That the Secretaries of the Society be instructed to notify Mr. DONOHOE of the acceptance of the Society, and to assure him that his gift is certain to promote and encourage the discovery and observation of comets, not only now, but always.

By a vote of the Directors Mr. DONOHOE's name has been placed on the roll of life-members.

It was also announced to the Society that Hon. C. F. CROCKER, a member of the Society, had generously offered to bear the expense of sending an expedition from the Lick Observatory to Cayenne, South America, to observe the total solar eclipse of December 21, 1889. The Regents of the University have authorized Messrs. BURNHAM and SCHAEBERLE to take part in this work, and to use such instruments of the Lick Observatory as may be useful. Mr. F. G. BLINN, of Oakland, and Captain R. L. PHYTHIAN, U. S. Navy, Superintendent of the U. S. Naval Observatory at Washington, have also materially aided the expedition by the loan of instruments and apparatus. Messrs. BURNHAM and SCHAEBERLE will probably leave California about November 1st, and arrive at Cayenne about December 1st, 1889. The eclipse will be observed at Cayenne by an English party under Rev. S. J. PERRY, F. R. S., Director of the Stonyhurst College Observatory, and in Africa by two parties, one under Professor D. P. TODD, of Amherst College, the other under Mr. TAYLOR, F. R. A. S., Assistant in the Private Observatory of Mr. A. A. COMMON, F. R. S., of London.

Papers were then read to the Society by Mr. KEELER, on the photography of the Corona in full sunshine, etc.; by Mr. LEUSCHNER, on the orbit of comet Barnard (June 23); by Mr. HILL, on occultations of *Jupiter* during 1889; by Mr. HOLDEN, on the Helical Nebulæ. These papers are printed in full or in abstract in the preceding pages.

Mr. BARNARD exhibited a beautiful negative of a portion of the Milky Way (R. A. 18h. 11m., Dec., 20° S.) near *Jupiter*, which he took on July 24, with the Willard photographic lens of the Lick Observatory,* giving an exposure of 1h. 48m.

The Society then adjourned to meet at the Lick Observatory September 28, 1889.

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* Bought by Hon. C. F. CROCKER for the expedition to observe the eclipse of December 21, 1889.

OFFICERS OF THE SOCIETY.

EDWARD S. HOLDEN (Lick Observatory),	*President*
WM. M. PIERSON (76 Nevada Block, S. F.),	*Vice-Presidents*
W. H. LOWDEN (213 Sansome Street, S. F.),	
FRANK SOULÉ (Students' Observatory, Berkeley),	
CHAS. BURCKHALTER (Chabot Observatory, Oakland),	*Secretaries*
J. M. SCHAEBERLE (Lick Observatory),	
E. J. MOLERA (850 Van Ness Avenue, S. F.).	*Treasurer*

Board of Directors—Messrs. ALVORD, BOERICKE, BURCKHALTER, GIBBS, GRANT, HOLDEN, LOWDEN, MOLERA, PIERSON, SCHAEBERLE, SOULÉ.

Finance Committee—Messrs. GIBBS, PIERSON, MOLERA.

Committee on Publication—Messrs. DEWEY, TREAT, ZIEL.

Committee on the Comet Medal—Messrs. HOLDEN (*ex officio*), SCHAEBERLE, BURCKHALTER.

NOTICE.

Members are requested to preserve the copies of the Publications of the Society as sent to them. At certain intervals a title page and index of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with Mr. BURCKHALTER, at the rooms of the Society, 408 California Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

No. 4. SAN FRANCISCO, CALIFORNIA, SEPTEMBER 28, 1889.

ON THE PHOTOGRAPHIC BRIGHTNESS OF THE FIXED STARS.

BY J. M. SCHAEBERLE, ASTRONOMER OF THE LICK OBSERVATORY.

The investigations relating to the photographic brightness of the fixed stars contained in this paper were made with the aid of an equatorially mounted DALLMEYER portrait-lens of $6^{in}.05$ aperture, loaned to this Observatory by the U. S. N. Observatory for the purpose of photographing the next total solar eclipse at Cayenne, South America.

Professor HOLDEN placed this instrument in my charge, and requested me to make a series of experiments on atmospheric absorption of the light, and on the photographic brightness, of the fixed stars, so that the extended work of the same character which it is intended to execute in South America could be more intelligently and profitably performed.

The photographic focus was carefully determined by making several series of short exposures, and trails, of bright stars both inside and outside of the adopted position of the plate. The position of the plate for each setting was read off on a scale which I cut on the tube. All the exposures were made on 5×7 Seed 26 plates.

Leaving the work relating to atmospheric absorption to a future paper, let us consider the subject of the photographic brightness of stars as determined by the dimensions of their circular images on the sensitive plate. (As the dimensions—widths—of the trails could only be accurately determined for the brighter stars, I finally avoided examining trails for this special investigation.)

As the whole subject was comparatively new to me, several weeks were spent in work of an experimental character. A careful study of the data given on the exposed plate was made with the aid of our excellent measuring engine. I finally came to the conclusion that the diameter of the image of an "over-exposed" star could be used

to determine the star's brightness with accuracy. To find the law of variation of the diameter of the photographic image for a variation of both the aperture of the objective and the time of exposure, seven different stops, varying in diameter from 5.41 inches to 1.91 inches, were used, and exposures of 1^s, 2^s, 4^s, 8^s, 16^s, 32^s, 64^s, and 128^s duration made for each stop. In order to be sure of the effective aperture of the stops, they were placed centrally in front of the objective, and not in the usual place between the lenses. The diameters of these stops, which we will number 1, 2, 3, etc., are as follows:

No.	1	2	3	4	5	6	7
Diameter	in. 5.41	in. 4.59	in. 3.81	in. 3.31	in. 2.72	in. 2.31	in. 1.91

The figures in the following table give the diameters of the images of *Polaris*, in inches, as measured on one of the plates:

POLARIS.

EXPOSURE TIMES.	DIAMETERS OF IMAGE FOR DIFFERENT STOPS AND TIMES.						
	1	2	3	4	5	6	7
	in.	in.	in.	in.	in.	in.	in.
1^s	0.0048	0.0049	0.0049	0.0048	0.0045	0.0041	0.0036
2	58	57	59	52	47	45	37
4	68	66	58	59	57	55	40
8	78	74	70	72	40	—	48
16	81	—	72	64	56	52	50
32	92	72	74	76	65	61	53
64	116	90	91	86	78	68	59
128	139	117	102	96	84	78	67

I tried to represent these numbers by various equations of the second and third degrees as functions of the aperture and time, but finally concluded that they could only be represented by an equation of the n^{th} degree, or, in other words, that the logarithms of the variables enter into the equation. I then made a similar set of exposures, using *α Lyræ* (discussed further on), and found that the function which represented the diameters was of precisely the same form. I

have deduced the following general expression for the diameter of the photographic image of a star:

$$d = \alpha + \beta . \log D + \gamma . D . \log t \quad . \quad . \quad . \quad . \quad . \quad (1)$$

In which, for a given star,

d = the measured diameter of the photographic image;
α = a constant depending only on the sensitive plate and the atmospheric state;
β = " " " " " " " "
γ = " " " " " " " "
D = the effective diameter of the objective (stop);
t = the time of exposure expressed in seconds.

In order to determine the most probable values of α, β and γ for a particular case it will be more convenient to place

$$\alpha + \beta \log D = a \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$\gamma D = b \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Equation (1) then becomes

$$d = a + b \log t \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

In selecting the unit for D it must be remembered that with a small stop the images, for comparatively short exposures, are small and faint. Greater accuracy may therefore be expected from large apertures. I have accordingly chosen six inches (6^{in}) as the unit of *D*. The diameters of the stops in terms of this unit are therefore as given below:

Stop.	1	2	3	4	5	6	7
Diameter	0.902	0.765	0.635	0.552	0.453	0.385	0.318
Log. of Diam.	-0.045	-0.116	-0.197	-0.258	-0.344	-0.415	-0.498

Equation (1) shows that when $t = 1^s$ and $D = 6^{in}$, we have $d = a$; in other words, a is the diameter of the photographic image of the star for an aperture of six inches and an exposure time of one second.

Taking *Polaris* for the standard star, the above-measured diameters give the following values for a and b as found by the method of least squares; each equation of condition being of the form:

$$d = a + b \log t$$

Stop.	a	b
	in.	in.
1	0.0051	0.0032
2	53	22
3	51	19
4	46	22
5	43	15
6	43	13
7	36	12

To find the value of α and β we have the following equations of condition

$$\begin{aligned}
\alpha - 0^{in}.045\,\beta &= 0^{in}.0051 \\
\alpha - \phantom{0^{in}}.116\,\beta &= \phantom{0^{in}}.0053 \\
\alpha - \phantom{0^{in}}.197\,\beta &= \phantom{0^{in}}.0051 \\
\alpha - \phantom{0^{in}}.258\,\beta &= \phantom{0^{in}}.0046 \\
\alpha - \phantom{0^{in}}.344\,\beta &= \phantom{0^{in}}.0043 \\
\alpha - \phantom{0^{in}}.415\,\beta &= \phantom{0^{in}}.0043 \\
\alpha - \phantom{0^{in}}.498\,\beta &= \phantom{0^{in}}.0036
\end{aligned}$$

The solution of which by the method of least squares gives for values of α and β

$$\alpha = 0^{in}.0055 \qquad\qquad \beta = 0^{in}.0033$$

The diameter of the photographic image of *Polaris* for six inches aperture and one second exposure is therefore, for this particular case, $0^{in}.0055$.

The independent values of γ given by the expression $\gamma = \frac{b}{D}$ are

b	D	γ			
in.		in.			
0.0032	0.902	0.0035	from	8 different exposures with Stop	1
22	.765	0029	"	7 ditto	2
19	.635	0030	"	8 ditto	3
22	.552	0040	"	8 ditto	4
15	.453	0033	"	8 ditto	5
13	.385	0034	"	7 ditto	6
12	.318	0038	"	8 ditto	7

Taking the mean of the values of γ, we have for the images of *Polaris* the equation

$$d = 0^{\text{in}}.0055 + 0.0033 \log D + 0.0034\, D \log t \quad . \quad . \quad (5)$$

The residuals obtained by subtracting the diameters computed by the above formula from the measured diameters are as follows:

POLARIS.

EXPOSURE TIME.	OBSERVATION—COMPUTATION.						
	1	2	3	4	5	6	7
	in.	in.	in.	in.	in.	in.	in.
1s	−0.0005	−0.0002	0.0000	+0.0001	+0.0001	0.0000	−0.0003
2	− .0005	− .0002	+ .0004	.0000	− .0001	.0000	− .0004
4	− .0004	− .0001	− .0004	+ .0001	+ .0004	+ .0006	− .0005
8	− .0003	− .0001	+ .0002	+ .0008	——	——	.0000
16	− .0009	——	− .0003	− .0005	− .0004	− .0005	− .0002
32	− .0008	(0018)	− .0007	+ .0001	.0000	.0000	− .0001
64	− .0007	− .0008	+ .0003	+ .0006	+ .0008	+ .0003	+ .0001
128	− .0020	− .0011	+ .0008	+ .0010	+ .0010	+ .0009	+ .0006

The diameters of the images of *α Lyræ* on a plate exposed Sept. 2, are as follows:

α LYRÆ.

EXPOSURE TIME.	DIAMETERS OF IMAGES FOR DIFFERENT STOPS AND TIMES.						
	1	2	3	4	5	6	7
1s	0.0093	0.0088	0.0073	0.0061	0.0055	0.0046	0.0045
2	114	91	—	70	63	55	48
4	123	96	—	80	70	—	57
8	148	107	102	109	80	71	66
16	* —	125	114	114	88	—	72
32	* —	146	133	122	104	—	83
64	* —	169	151	145	119	—	—

* In this table, as in the one for *Polaris*, the missing figures belong to cases in which the images, on account of imperfect pointing, are not circular but elongated; while for stop 1 the images are so close together that the larger ones overlap, and, consequently, were not used.

The equation which fairly represents these diameters is:

$$d = 0^{in}.0070 + 0^{in}.0050 \log D + 0.0074 \, D \log t \quad . \quad . \quad (6)$$

the individual values of γ, found by dividing each b by the corresponding D, are:

b	$\div$	D	$=$	γ
0.0067	$\div$	.902	$=$	0.0074
46		.765		.0060
42		.635		.0066
46		.552		.0083
34		.453		.0075
30		.385		.0078
27		.318		.0085

The observed values of d, minus the values computed by equation (6), are as given below:

α Lyræ.

Exposure Time.	Observation—Computation.						
	1	2	3	4	5	6	7
1ˢ	+0.0005	(+0.0024)	+0.0013	+0.0004	+0.0002	-0.0002	0.0000
2	+ .0006	.0010	——	+ .0001	.0000	- .0001	- .0004
4	- .0005	- .0002	——	- .0001	- .0003	——	- .0002
8	——	- .0008	.0000	+ .0015	- .0003	- .0002	.0000
16	——	- .0007	- .0002	+ .0008	- .0005	——	- .0001
32	——	- .0003	- .0001	- .0004	+ .0001	——	+ .0003
64	——	+ .0003	+ .0006	- .0009	+ .0006	——	——

From equation (6) we infer that, for six inches aperture and one second exposure time, the diameter of *α Lyræ's* image on this particular plate is $0^{in}.0070$. Comparing equation (6) with equation (5) we learn that the increase in the diameter of the image of *α Lyræ* on this plate for any t is 2.2 times as rapid as it is in the case of *Polaris* for the same t on the plate first described; so that, if other things were equal, the difference between the photographic energy of two stars could be more accurately determined from comparatively long exposures than from short ones. (The *rate* of increase, of course, varies inversely as t.)

Now, let

$$d = \alpha_0 + \beta_0 \log D + \gamma_0 \, D \log t \quad . \quad . \quad . \quad . \quad (7)$$

be the equation giving the diameters for a particular star taken as a standard, and let

$$d' = \alpha + \beta \log D_0 + \gamma D_0 \log t \quad . \quad . \quad . \quad . \quad (8)$$

be the equation which gives the diameter of the image of *any* star for the *constant aperture* D_0 (unity = 6^{in}); then if Q represents the particular aperture in equation (7) which, for the same value of t makes $d = d'$, the reciprocal of this quantity, or $\frac{1}{Q}$, substituted in place of D_0 must, for all values of t, satisfy equation (8) for $d' = d$ if the assumed law* is theoretically exact. Q, then, becomes a measure of the square root of the relative brightness of the two stars, since, if we assume that the amount of energy required to produce a given impression on a given plate is always the same, whatever the unit of energy (intensity) may be, the total amount of energy for the same telescope can be considered as varying directly with the area of the aperture, or with D^2. Hence, if B_0 and B denote respectively the brightness of the standard and comparison stars, we can at once write:

$$\left(\frac{Q}{D_0}\right)^2 = \frac{B}{B_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Q being that value of D which when substituted in the equation for the standard star (equation 7) will make $d = d'$. In other words, *Q is the diameter of the aperture which the standard star would require to produce, in the time t, an image having the same diameter as that of any other star photographed with an aperture* D_0 (= six inches) *in the same time t.* Equation (7) can therefore be written:

$$d' = \alpha_0 + \beta_0 \log Q + \gamma_0 Q \log t \quad . \quad . \quad . \quad . \quad (11)$$

Let us now take the equations deduced from the measured diameters of the images of *Polaris* and *α Lyræ*, and see to what degree of accuracy the necessary theoretical relations between Q and D_0 will represent the observed data. For $d = d'$ we have the equation:

$$0.0055 + 0.0033 \log Q + 0.0034\, Q \log t = 0.0070 + 0.0030 \log D_0 + 0.0074\, D_0 \log t$$

After a few trials, for different values of t, we obtain the approximate value $D_0 = 0.48$ when $Q = 1$, and, according to the above considerations, we should also have $Q = 2.10$ when $D_0 = 1$. Both of these conditions should be fulfilled for all values of t.

As the images of the two stars are on different plates I have not thought it worth while to derive a more accurate relation between Q and D_0 for this particular case.

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* The law expressed in equations (1) and (7).

The approximate relation will, however, serve to show the agreement between our theory and the data derived from actual observations.

The accompanying table contains the computed values of d and d' for each t, for reciprocal values of Q and D_0:

Exposure Time.	$D_0 = 1.00$ $Q = 2.10$		$D = 0.48$ $Q = 1.00$	
	Polaris d	*α Lyræ* d'	*Polaris* d	*α Lyræ* d'
1ˢ	0.0070	0.0066	0.0055	0.0054
2	.0087	.0092	.0065	.0065
4	.0109	.0114	.0075	.0075
8	.0130	.0140	.0086	.0086
16	.0151	.0159	.0096	.0097
32	.0173	.0181	.0106	.0107
64	.0195	.0204	.0117	.0118

If the two sets of star images had been impressed upon the same plate, we would have inferred the photographic brightness of *α Lyræ* to be about 4.4 times that of *Polaris*.* As, however, the diameters of the star images on different plates taken from the same box are not always the same for equal exposures, it became necessary to make a separate investigation covering this particular phenomenon.

I found that if we express the diameters of the image of *Polaris* on any plate in terms of the diameters given on the plate for which equation (5) holds good (which we will call the standard plate), we have only to multiply the second member of equation (5) by such a number x that for a given t the measured d will be satisfied. From a series of comparisons I find that x is practically constant for the different values of t. The general equation for any No. 26 Seed plate exposed in the stellar focus of the particular telescope used in these investigations I therefore assume to be

$$\frac{d}{x} = 0^{\text{in}}.0055 + 0^{\text{in}}.0033 \, (\log Q + Q \log t) \qquad . \quad . \quad . \quad (12)$$

since, for all practical purposes, β_0 and γ_0 in equation (5) are the same.

* Neglecting atmospheric absorption.

To find the value of Q from this equation we can write:

$$\log Q + Q \log t = \log (Q\, t^{Q}) = \frac{d}{0.0033 \,.\, x} - 1.67 \quad . \quad (13)$$

In order, however, to facilitate the determination of Q for certain observed values of d and t, I have computed the following table, by means of which Q can be obtained by simple interpolation.

The horizontal argument is Q, the vertical argument is t, and the tabular function corresponding to these arguments is the measured d of equation (13) for $x = 1.00$.

Exposure Time.	Q.									
	0.40	0.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	4.00
2^s	0.0046	0.0060	0.0070	0.0078	0.0085	0.0091	0.0098	0.0103	0.0109	0.0114
4	.0050	.0068	.0081	.0093	.0105	.0115	.0125	.0135	.0145	.0154
8	.0054	.0078	.0093	.0109	.0125	.0139	.0153	.0167	.0181	.0194

If for a particular plate any measured diameter is d, the argument for entering the above table is $x.d$, and x is to be taken as a constant for the same plate.

We will now give a few examples illustrating the application of the formulas for determining the brightness of the fixed stars:

Example I. On September 5th, 1889, *Polaris*, α *Aurigæ*, γ *Cephei* and α *Tauri* were photographed on the same plate with exposures of 2^s, 4^s and 8^s. The measured diameters are:

Exposure Time.	Measured Diameters ($= d$).			
	Polaris.	α *Aurigæ.*	γ *Cephei.*	α *Tauri.*
2^s	0.0064	0.0081	0.0042	0.0060
4	.0074	.0090	.0052	.0061
8	.0080	.0109	.0056	.0072

The aperture being six inches for all the exposures, we first assume the plate to be a standard one, and find d with the argument $Q = 1$, either by means of equation (5) or, by interpolation, from the table:

POLARIS.

EXPOSURE TIME.	COMPUTED d.	O - C.
2^s	0.0065	- 0.0001
4^s	.0074	0.0000
8^s	.0085	- 0.0005

As the measured values are slightly smaller than those given by our assumed standard plate, we give x such a value that the (O – C) quantities will nearly balance each other. Placing $x = 1.03$ and multiplying the observed values of d by 1.03, the residuals (O – C) become respectively +0.0001, +0.0001, and – 0.0003.

To obtain the value of Q, by direct computation, for any star whose image is on this particular plate, we would therefore use the equation

$$\log Q + Q \log t = \frac{d}{0.0034} - 1.67 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

in which d is the measured diameter corresponding to the time t.

The tabular values at once give the desired quantities by interpolation, first multiplying each measured d by 1.03 for the argument:

EXPOSURE TIME.	VALUES OF $Q = \sqrt{B}$.			
	Polaris.	*α Aurigæ.*	*γ Cephei.*	*α Tauri.*
2^s	1.04	1.89	0.32	0.84
4^s	1.05	1.60	0.32	0.69
5^s	0.90	1.68	0.47	0.73
Mean	1.00	1.72	0.42	0.75

Using the mean values of Q, we obtain the following residuals:

EXPOSURE TIME.	OBSERVATION – COMPUTATION.			
2^s	0.0000	+0.0003	- 0.0003	+0.0003
4	+ .0002	- .0004	+ .0002	- .0003
8	- .0003	- .0002	+ .0003	- .0001

If we use the familiar expression for the light-ratio of visual magnitudes,

$$B = (0.4)^{m-1}$$

(in which B and m are respectively the visual brightness and visual magnitude of any star) for expressing also the light-ratio for the photographic magnitudes m', we can write

$$m' = 1 - \frac{\log.(\kappa \cdot Q^2)}{\log.0.4} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (17)$$

in which κ is a constant depending upon the photographic magnitude of the standard star. For the purpose of comparing the photographic with the visual magnitudes, let us take *Polaris* as the standard star, and assume its photographic magnitude to be 2.00; equation (17) becomes

$$m' = 2 - \frac{\log Q^2}{0.4}$$

The values of m', for certain values of Q, can be taken from the accompanying table, which I have computed for illustration:

Q	0.00	0.20	0.40	0.60	0.80
0.00		5.49	3.99	3.11	2.48
1.00	2.00	1.60	1.27	0.98	0.72
2.00	0.50	0.29	0.10	−0.07	−0.24
3.00	−0.39	−0.53	−0.66	−0.78	−0.90

From an inspection of the table and the values of Q given in the next example, we see at once that if we wish to avoid negative numbers for expressing some observed magnitudes we must either represent the magnitude of *Polaris* by a greater number or change the light-ratio.

I have tabulated the photographic magnitudes of the four stars, together with the probable errors. The visual magnitudes as given in Volume XIV, *Harvard College Observatory Annals*, and the differences between the photographic and visual magnitudes, are also added:

Star.	Photog. Mag.	Probable Error.	Visual Mag.	Vis. − Photog.
Polaris	2.02	±0.11	2.2	+0.2
α *Aurigæ*	0.82	0.11	0.2	−0.6
γ *Cephei*	4.20	0.28	3.4	−0.8
α *Tauri*	2.62	0.13	1.0	−1.6

EXAMPLE II. During the night of September 6, in bright moonlight, I made exposures of 2^s, 4^s and 8^s on *Polaris*, *α Lyræ*, *α Cygni*, *α Aquilæ*, and four hours later the same plate was exposed on *α Pisces Australis*, *β Ceti*, *α Aurigæ*, *α Arietis* and *α Andromedæ*. The measured diameters are tabulated below. For this plate we see at once that the differences between the observed and computed values of d are such that the (C – O) values (+0.0001, – 0.0003 and +0.0003) practically balance each other; hence we place $x = 1.00$ and use equation (13) (or the table) to obtain the values of Q given below. For the (O – C) values the computed quantities are obtained by substituting the mean values of Q in equation (12):

EXPOSURE TIME.	MEASURED VALUES OF d.								
	Polaris.	*α Lyræ.*	*α Cygni.*	*α Aquilæ.*	*α Pis. Aust.*	*β Ceti.*	*α Aurigæ.*	*α Arietis.*	*α Androm.*
2^s	0.0066	0.0103	0.0092	0.0090	0.0077	0.0049	0.0075	0.0053	0.0079
4	.0072	.0134	.0116	.0106	.0087	.0054	.0094	.0063	.0090
8	.0088	.0169	.0136	.0129	.0099	.0060	.0106	.0066	.0116
EXPOSURE TIME.	RESULTING VALUES OF $Q = \sqrt{B}$.								
2^s	1.04	3.20	2.46	2.33	1.55	0.49	1.45	0.60	1.66
4	0.92	3.16	2.44	2.04	1.40	0.49	1.63	0.69	1.50
8	1.07	3.26	2.31	2.11	1.35	0.50	1.52	0.60	1.77
	1.01	3.21	2.30	2.15	1.43	0.49	1.53	0.63	1.64
EXPOSURE TIME.	THE MEAN VALUES OF Q, GIVE THE RESIDUALS,								
2^s	+0.0000	0.0000	+0.0002	+0.0003	+0.0002	0.0000	– 0.0002	– 0.0001	0.0000
4	+ .0001	– .0001	+ .0003	– .0002	.0000	.0000	+ .0003	+ .0003	– .0004
8	– .0003	+ .0002	.0000	– .0001	– .0003	+ .0001	+ .0001	– .0001	+ .0005

The numbers expressing the photographic brightness of each star in terms of that of *Polaris* are therefore, in the above order, 10.3, 5.3, 4.6, 2.0, 0.2, 2.3, 0.4 and 2.7. The only star of the list which was near to the zenith at the time its image was formed on the photographic plate is *α Lyræ;* the effect of moonlight, atmospheric

absorption and haze would therefore be at a minimum for this star, and its relative brightness would apparently be near a maximum. The same remarks apply to the results given in the next table as in the last example:

Star.	Photog. Mag.	Probable Error.	Visual Mag.	Vis. – Photog.
Polaris	+ 1.95	± 0.05	+ 2.2	+ 0.2
α *Lyræ*	— 0.53	± 0.02	+ 0.2	+ 0.7
α *Cygni*	+ 0.10	± 0.03	+ 1.5	+ 1.4
α *Aquilæ*	+ 0.34	± 0.06	+ 1.0	+ 0.7
α *Pis. Aust.*	+ 1.22	± 0.05	+ 1.3	+ 0.1
β *Ceti*	+ 3.53	± 0.01	+ 2.1	— 1.4
α *Aurigæ*	+ 1.08	± 0.05	+ 0.2	— 0.9
α *Arietis*	+ 3.01	± 0.07	+ 2.0	— 1.0
α *Androm.*	+ 0.93	± 0.07	+ 2.1	+ 1.2

No corrections for absorption, etc., have as yet been applied to the above results, which consequently refer to the apparent magnitude at the instant of exposure. The last column of the above table plainly shows that we can make no definite *a priori* estimate as to what the photographic magnitude of a star is if we simply know its visual magnitude. There is therefore no advantage (as Professor Holden has pointed out in his "Memorandum" to the Paris Photographic Conference) in following the methods used for visual magnitudes.

It is evident that we must first know the law of atmospheric absorption of the photographic rays before we can determine the true relative brightness of the stars; since each observed brightness requires a certain plus correction, depending directly upon the zenith distance, to reduce it to the brightness which would have been obtained at the zenith. Or each observed brightness could be reduced to what it would be at a certain zenith distance, as, for instance, that of the celestial pole at a given place. The photographs already taken show that this correction is quite sensible, even at small zenith distances. From some preliminary reductions I find that for this Observatory (altitude 4209 feet) the absorption of stellar

photographic brightness at 80° zenith distance is considerably more than fifty per cent. of the brightness reduced to 0° zenith distance. After a complete series of observations bearing upon this subject has been obtained at sea-level near the earth's equator, I hope to give, in a more or less complete state, the photographic magnitudes of a large number of the brighter stars in both hemispheres. Just how far down the scale of magnitudes the formulæ will hold good I am, as yet, unable to say.

In photographing faint stars the exposure time should evidently be so long as to make the diameters of the disks as great or greater than the faint penumbral image which, in the telescope used, surrounds the primitive umbral image in short exposures on faint stars; when this precaution is taken, it seems that the formulæ give consistent results, judging from a few experimental exposures. This form of image for short exposures on faint stars may, of course, be peculiar to this particular telescope. Too much stress cannot be laid upon the statement, *that if reliable results are to be obtained*, the objective must be of the first order of excellence and *the plate must be kept exactly in the stellar focus.*

Throughout this whole discussion I have purposely avoided bringing in any relation between aperture and focal length, as it seems probable that different telescopes must be compared before any definite conclusions can be drawn.

The results contained in the present paper are only to be considered as preliminary to a much more extended investigation to be undertaken in South America under the auspices of this Observatory, made possible through the generosity of Col. CROCKER.

In conclusion, I wish to express my obligations to Professor HOLDEN, Director of this Observatory, for his readiness in placing at my disposal everything which could in any way aid me in past and future investigations; for his practical help and advice relating to a subject which has claimed his attention for some time past, and which is destined to become the most important method of investigation in our science, viz: *Astronomical Photography.*

I also wish to thank Mr. BURNHAM for his kind and willing assistance in the photographic work.

J. M. SCHAEBERLE.

LICK OBSERVATORY, September 21, 1889.

ON THE ESTABLISHMENT OF A STANDARD MERIDIAN LINE FOR SANTA CLARA COUNTY, CALIFORNIA.

By James E. Keeler.

A few months ago, at the suggestion of Professor Holden, Mr. Chas. Herrmann, County Surveyor of Santa Clara county, and Mr. A. T. Herrmann, Surveyor and Civil Engineer, obtained the permission of the County Supervisors to establish a standard meridian line in San José, for the benefit of surveyors, with a sufficient sum of money to provide suitable monuments.

It was agreed that the astronomical staff of the Observatory should make the necessary observations without expense to the county, and I was appointed to carry out the work.

Absolute directions on the earth can only be determined by reference to the heavenly bodies. The magnetic needle has been and still is extensively used as a secondary means of determining directions, but the angle which the magnetic needle makes with the true meridian is constantly changing, and is, moreover, subject to sudden and irregular variations, so that, even with the greatest precautions, the compass is an unsafe guide. Ignorance of these facts, or of the amount of necessary allowance from lack of a suitable standard of reference, has given rise to an endless amount of litigation in this country. It is safe to say, that if each county in the Union had legally established a standard meridian in the early days of its settlement, the gain to the country would have to be estimated by hundreds of thousands of dollars.

The remedy for the evils resulting from the secular change of the magnetic declination has been repeatedly pointed out, ever since the days of Rittenhouse. Prof. Gillespie, in his well-known work on Land Surveying, says (p. 210): "The only complete remedy for the disputes, and the uncertainty of bounds, resulting from the continued change in the variation, is this: Let a meridian, *i. e.*, a true north and south line, be established in every town or county, by the authority of the State; monuments, such as stones set deep in the ground, being placed at each end of it. Let every surveyor be obliged by law to test his compass by this line, at least once in each year. . . . . Let the variation thus ascertained be inserted in the notes of the survey and recorded in the deed. Another surveyor, years or centuries afterward, could test his compass by taking the

bearing of the same monuments, and the difference between this and the former bearing would be the change of variation. He could thus determine, with entire certainty, the proper allowance to be made in order to retrace the original line, no matter how much, or how irregularly, the variation may have changed, or how badly adjusted was the compass of the original survey."

But although these evils have been thus forcibly stated, even in the text-books of every school, and the remedy so clearly pointed out, very little interest has been taken in the matter by State authorities. Professor HOLDEN, while Director of the Washburn Observatory, once proposed to establish a standard meridian in every county-seat in the State of Wisconsin, for the bare personal and traveling expenses of an observer, an offer which was declined without thanks.

There is no doubt that the Lick Observatory would assist in such a plan for California, by every means in its power, should the proper authorities be willing to pay the bare expense of the undertaking.

It may be noted that the value of a standard line of reference is particularly great in a newly settled country, where the compass is more relied upon than it is in older communities with well-established boundaries and landmarks.

The scene of our operations in San José was what is known as the "Meridian Road," because it is supposed to be in the line of the Mt. Diablo meridian. It has been the practice of surveyors to test their instruments by sighting up and down this road, which, however, contains no marks sufficiently definite to admit of a precise determination by this method. The north end of the road terminates at a high board fence which forms the southern boundary of the Fair Ground, and on a shelf secured to this fence a mark was put up, consisting of a hole one-half inch in diameter in a thin plate, illuminated from behind by a bull's-eye lantern. Two thousand feet south of the mark a substantial pier of brick and cement was built for the support of the instrument. The mark was as nearly in the meridian of the pier as could be determined with the aid of a compass. At the pier it subtended an angle of 4″, and to the naked eye appeared as a star of about the first magnitude.

The instrument employed was the REPSOLD altazimuth briefly described in Vol. I, Publications of the Lick Observatory, and more completely in my report on the geographical position of Norman, California, in the Reports on Observations of the Total Eclipse of January 1, 1889, published by the Lick Observatory. It has vertical and horizontal circles ten inches in diameter, read to 2″ by microme-

ter microscopes, or by estimation to 0″.2. All necessary attachments are provided for exact astronomical work. The time-piece used was a sidereal chronometer, Negus 1720.

Preliminary observations were made on the night of August 5th, and more accurate ones on August 6th and 7th. The azimuth of the mark was determined by alternate readings on the mark and on *Polaris* near eastern elongation, the instrument being reversed during the measurements to eliminate the error of collimation. The latitude of the pier was determined, with sufficient accuracy, by measuring the zenith distances of four stars with the vertical circle, and the local sidereal time by using the altazimuth as a transit instrument. No elaborate time observations were made, as a knowledge of the time to within one second is amply sufficient for computing the small reductions to elongation. The horizontal circle was turned one-third round on August 7th, in order to bring different divisions under the microscopes.

Ten observations of the mark and ten of *Polaris*, on August 6th, made the mark 1° 22′ 48″.0 west of the vertical circle passing through the point of elongation. The computed azimuth of the star corrected for diurnal aberration, was 1° 37′ 7″.2, hence the azimuth of the mark was + 0° 14′ 19″.2.

From six observations of the star and six of the mark, on August 7th, the mark was west of the star 1° 22′ 50″.6. The computed azimuth of the star was 1° 37′ 6″.8, and hence the azimuth of the mark was + 0° 14′ 16″.2. The adopted azimuth of the mark was 14′ 17″.7 east, which, at a distance of 2000 feet, corresponds to 8 feet 3.8 inches, and the mark was moved this distance to the west to bring it into the meridian of the centre mark on the pier. The estimated probable error of the meridian is 2″, or about one-quarter of an inch at a distance of 2000 feet, a quantity thirty times smaller than the smallest angle which is measured with ordinary surveying instruments. From the above data permanent monuments will be established by the Messrs. HERRMANN.

For the convenience of those who cannot avail themselves of this meridian line, I have computed the following table of azimuths and times of elongation of *Polaris* for the latitude and longitude of San José. The azimuths are given to the nearest 10″; the times of elongation in *Standard Pacific Time* to the nearest minute. For San Francisco the azimuths must be increased by 40″, and the times of elongation will be about two minutes later. An error of thirteen minutes in the time of elongation will produce an error of only 10″ in the azimuth. The formulæ from which this table was com-

puted may be found in DOOLITTLE'S Practical Astronomy (p. 527).

If the meridian is determined from observations of *Polaris* near elongation by a surveyor's transit, the line of collimation must be adjusted with especial care, so as to travel on a truly vertical line. As there are several minutes near elongation during which the azimuth of the star does not differ appreciably from the tabulated value, it is better to make two observations of the star, one with reversed position of the telescope, and take the mean of the readings of the horizontal circle. It must be remembered that the reading of the compass needle, when the sight line of the instrument is in the meridian, is not necessarily the magnetic declination, since the line of zeros of the compass circle may not be in the same plane with the line of collimation (as, of course, it should be). The reading of the needle will, however, be the declination *for that particular instrument*, and true bearings can be taken just as well as if the adjustment were perfect.

TABLE OF AZIMUTHS AND TIMES OF ELONGATION OF *POLARIS*.

(Computed for the latitude and longitude of San José, Cal., by J. E. KEELER.)

DATE.			W. ELONGATION.			E. ELONGATION.			AZIMUTH.		
			h.	m.		h.	m.		°	′	″
1889.	Sept.	6....	8	19	A.M.	8	25	P.M.	1	37	00
	"	16....	7	39	"	7	46	"	1	36	50
	"	26....	7	00	"	7	06	"	1	36	50
	Oct.	6....	6	21	"	6	27	"	1	36	40
	"	16....	5	42	"	5	48	"	1	36	40
	"	26....	5	03	"	5	08	"	1	36	30
	Nov.	5....	4	23	"	4	29	"	1	36	30
	"	15....	3	44	"	3	50	"	1	36	20
	"	25....	3	05	"	3	11	"	1	36	20
	Dec.	5....	2	25	"	2	31	"	1	36	20
	"	15....	1	46	"	1	52	"	1	36	10
	"	25....	1	06	"	1	12	"	1	36	10
1890.	Jan.	4....	12	27	"	12	33	"	1	36	10
	"	14....	11	43	P.M.	11	53	A.M.	1	36	10
	"	24....	11	04	"	11	14	"	1	36	10
	Feb.	3....	10	24	"	10	34	"	1	36	10
	"	13....	9	45	"	9	55	"	1	36	10
	"	23....	9	06	"	9	16	"	1	36	10

Date.			W. Elongation.			E. Elongation.			Azimuth.		
			h.	m.		h.	m.		°	′	″
1890.	Mar.	5....	8	26	P.M.	8	36	A.M.	1	36	20
	"	15....	7	47	"	7	57	"	1	36	20
	"	25....	7	07	"	7	17	"	1	36	20
	April	4....	6	28	"	6	38	"	1	36	30
	"	14....	5	48	"	5	58	"	1	36	30
	"	24....	5	09	"	5	19	"	1	36	40
	May	4....	4	30	"	4	40	"	1	36	40
	"	14....	3	50	"	4	00	"	1	36	40
	"	24....	3	11	"	3	21	"	1	36	50
	June	3....	2	32	"	2	42	"	1	36	50
	"	13....	1	53	"	2	03	"	1	36	50
	"	23....	1	14	"	1	23	"	1	36	50
	July	3....	12	35	"	12	44	"	1	36	50
	"	13....	11	55	A.M.	12	04	"	1	36	50
	"	23....	11	16	"	11	22	P.M.	1	36	50
	Aug.	2....	10	37	"	10	43	"	1	36	40
	"	12....	9	58	"	10	04	"	1	36	40
	"	22....	9	19	"	9	25	"	1	36	40
	Sept.	1....	8	40	"	8	46	"	1	36	30
	"	11....	8	00	"	8	06	"	1	36	30
	"	21....	7	21	"	7	27	"	1	36	30
	Oct.	1 ...	6	42	"	6	48	"	1	36	20
	"	11....	6	02	"	6	08	"	1	36	20
	"	21....	5	23	"	5	29	"	1	36	10
	"	31....	4	44	"	4	50	"	1	36	00
	Nov.	10....	4	05	"	4	10	"	1	36	00
	"	20....	3	25	"	3	31	"	1	36	00
	"	30....	2	46	"	2	52	"	1	35	50
	Dec.	10....	2	07	"	2	12	"	1	35	50
	"	20....	1	27	"	1	33	"	1	35	50
	"	30....	12	48	"	12	54	"	1	35	50
1891.	Jan.	9....	12	09	"	12	14	"	1	35	40

OCCULTATIONS OF STARS BY THE MOON.

OBSERVED BY A. O. LEUSCHNER.

DATE.	STAR.	MT. H. M. T. OF DISAPPEARANCE.	TELESCOPE.	POWER.	REMARKS.
1889.		h. m. s.			
Aug. 29	S D. (– 3°) 3459......	7 26 31.9	12-in.	80	Good.
" 29	S D. (– 3°) 3468......	8 5 26.6	"	"	
" 29	S D. (– 3°) 3469......	8 [10] 2.3	"	"	Minute probably 10.
" 29	S D. (– 3°) 3470......	8 13 40.1	"	"	Good.
" 30	S D. (– 8°) 3733......	7 27 22.5	"	"	"
" 30	S D. (– 8°) 3736......	7 39 51.1	"	"	"
" 30	S D. (– 9°) 3896......	7 58 51.5	"	"	"
" 30	S D. (– 8°) 3739......	8 17 24.7	"	"	"
" 30	S D. (– 9°) 3898......	8 19 24.0	"	"	"
Sept. 2	S D. (– 21°) 4494......	7 48 45.1	6-in.	75	"
" 2	S D. (– 21°) 4496......	7 50 32.9	"	"	"
" 2	S D. (– 21°) 4512......	9 10 59.9	12-in.	80	"
" 3	C Z. XVII h. 3871......	7 54 10.9	"	"	
" 3	C Z. XVII h. 3960......	8 13 50.7	"	"	
" 3	C Z. XVII h. 3978......	8 22 40.4	"	"	"
" 3	Anonymous 9.0 *17h. 58m. 26s.; – 23° 16'.0	9 12 46.4	"	"	"
" 3	Anonymous 9.0 *17h. 58m. 37s.; – 23° 18'.7	9 15 28.9	"	"	"
" 3	Anonymous 9.0 *17h. 59m. 12s.; – 23° 27'.3	9 34 24.5	"	"	"
" 3	W H Z. 175	9 50 8.6	"	"	"
" 3	Anonymous 8.0 *18 h. 0 m. 1 s.; – 23° 27'.0	10 0 0.2	"	"	"
" 3	Anonymous 8.5 *18h. 0 m. 41 s.; – 23° 26'.4	10 21 8.4	"	"	"
" 3	C Z. XVII h. 133.......	10 23 24.4	"	"	"

* These positions are for 1850.0.

CONJUNCTION OF MARS AND SATURN (SEPT. 20, 1889).

BY W. E. DOWNS.

The observations were made with the four-inch broken-tube comet-seeker. The times were noted on a watch running on P. S. T. A magnifying power of about thirty diameters was used.

$4^h\ 00^m$. First sight of *Saturn* and *Mars* in the telescope, through a very dense haze. *Mars* appeared as a very red, ill-defined spot of light. *Saturn* was very red, but less so than *Mars*. *Regulus* was also visible in the same field, to the south, and eight or ten times more distant from the planets than the space between them, and was of a lighter red color and fainter than either planet.

$4^h\ 15^m$. Both planets were visible to the naked eye, and easily separated as soon as seen.

$4^h\ 25^m$. *Saturn*, in the telescope, was of an orange color, and *Mars* of a light red.

$4^h\ 45^m$. To the eye *Saturn* was about as bright as *Polaris*, and *Mars* a little fainter.

$5^h\ 15^m$. Broad daylight approached fast. θ *Tauri* was still easily visible to the naked eye, and *c Orionis*, fifth magnitude, was barely visible and disappeared at $5^h\ 20^m$. θ *Orionis* disappeared at $5^h\ 23^m$, and *Saturn* and *Mars* at $5^h\ 30^m$.

$5^h\ 40^m$. *Saturn* and *Mars* were of a very light yellow color in the telescope; *Mars* being very slightly tinged with red. *Regulus* was white.

$5^h\ 50^m$. *Venus* was still easily visible to the eye. The clouds were getting ruddy in the east. *Saturn* and *Mars* were growing very rapidly fainter. After this *Regulus* was not kept in the field of the telescope.

$5^h\ 55^m$. *Mars* was easier to see than *Saturn*, the light from it being more vivid.

$6^h\ 00^m$. *Saturn* and *Mars* last seen in the telescope, and the sun's disc about two-thirds up. As the sun rose, its disc was round and red, and was crossed by horizontal cloud-belts.

$6^h\ 05^m$. *Venus* was still visible to the eye.

$6^h\ 10^m$. Lost sight of *Venus*, and did not again recover it. The sun was too far up to look at comfortably.

Regulus, *Saturn* and *Mars* formed an interesting triangular group, the angle at *Saturn* being slightly obtuse. This angle remained sensibly the same throughout the observations, although the planets were separating.

W. E. Downs.

Mt. Hamilton, 1889, Sept. 22.

A VERY REMARKABLE COMET.

By Edward E. Barnard.

On the morning of July 7th, a small comet was discovered by Mr. Brooks in the constellation Cetus. The moon coming into the morning sky blotted the comet out before any observations (except three at the Lick Observatory) could be made of it. When a sufficiently long interval was obtained the orbit was computed, and from the small inclination of its path to that of the earth it was at once suspected to be periodic; the suspicion has since been verified, the comet having a period of about seven or eight years. This was sufficient of itself to make it of more than ordinary interest. While observing this object in the first part of August I discovered that it was attended by at least four companions, which were moving through space in advance of the main comet. Two of these companions were discovered with the twelve-inch on August 1st, and the other two on August 4th with the great telescope. These last two were seen several times, but always remained too faint to be measured, and finally disappeared.

The two brighter companions were perfect miniatures of the larger comet, each having a small, fairly well-defined head and nucleus, with a faint, hazy tail, the more distant one being the larger and less-developed. The three comets were in a straight line, nearly east and west, their tails lying along this line. There was no connecting nebulosity between these objects, the tails of the two smaller not reaching each other or the large comet. To all appearance they were absolutely independent comets. The four which were discovered here I have named B, C, D, E, in the order of increasing right ascension, A being the original comet discovered by Mr. Brooks. As D and E disappeared after a few observations, they will not be again referred to; they were both north following C and in a line with it.

Since discovery I have measured these objects on every available

occasion, using the micrometer of the thirty-six-inch equatorial. It was found that these two were separating from the main comet quite rapidly; the more distant one moving the fastest. Towards the latter half of August the nearer companion B ceased to recede, and then underwent a remarkable change. It enlarged rapidly, becoming extremely diffused, and losing all appearance of central condensation. It could be measured only with the utmost difficulty. Throughout its visibility its position angle remained almost constant; towards the last, however, this angle began slowly but sensibly to increase as if the companion were in orbital motion. Unfortunately, at this most important point in the observations, the companion faded rapidly and totally from view, being last seen on the 5th of September. It disappeared as absolutely from the face of the heavens as did Biela's comet, which doubtless underwent a similar dissolution.

In the meantime the more distant companion continued to recede, and increased very much in brightness and size, until on August 31st it was perceptibly brighter than the larger comet! In the latter half of September it, too, became stationary with reference to the principal comet: remaining thus for some days, it began slowly to lessen its distance, having attained a maximum distance of 356″. This object has also undergone a change in appearance similar to that in the lost companion. Its tail has disappeared, and the head has become large and much diffused, its brightness in the meantime having diminished very greatly. The position angle of this object has remained remarkably constant for the past two months; it attained a maximum of about 62° in the middle of September; since then it has been slowly decreasing, until it is now the same as when first observed.

Measures of the companion B on twenty-two nights were obtained, and up to the present date measures of C have been made on forty nights.

The following, selected from the observations, will give an idea of the relative positions of this group:

		°		″
Aug. 1.	Position angle A and B,	59.4;	distance A and B,	64.1.
Sept. 4.	" " " " "	65.0	" " " " "	71.5.
Aug. 4.	" " A and C,	61.5	" A and C,	267.6.
Sept. 15.	" " " " "	62.1	" " " " "	356.4.
Sept. 30.	" " " " "	61.4	" " " " "	352.1.

It is hoped that through measures of the relative positions of

these bodies we shall be enabled to detect orbital motion of the smaller ones about the larger. If this were shown to exist, we should at once have the means of determining the mass of this cometary system. These changes may, however, be due to perspective.

So far as we know, the phenomenon presented by this comet is extremely rare. It is needless to repeat the story of Biela's comet. In 1845 it separated into two distinct comets, which traveled side by side, and returning at the appointed time, they were seen to be widely separated—indeed, moving in distinctly separate paths; they then disappeared, to be seen no more in the heavens. One of the comets of 1861 was seen double for a few days. Some companions were seen moving with the Great Comet of 1882, but no measurements were made. This covers our knowledge of multiple comets, or comets with companions, unless, indeed, we accept the evidence of the Chinese records, which possibly describe comets that consisted of two or more parts.

MT. HAMILTON, September 30, 1889.

NOTE.—In order not to delay the publication of the present number, the printing of two papers on Drawings of *Jupiter* in the years 1875-1883, by Messrs. HOLDEN and BARNARD, is postponed to the next number.

NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

PHOTOGRAPHING THE MILKY WAY.

The great success obtained by Mr. BARNARD in his preliminary experiments with the WILLARD portrait lens ($a = 5.9$, $f = 30.7$) has led to the determination to employ it in making a systematic study of the Milky Way by photography. For this purpose it has been mounted at the object-glass end of the tube of the great telescope, and arrangements made by which the lens can be capped and uncapped from the eye end. The driving clock of the great telescope (with a control) will keep the camera directed at the star-group chosen during an exposure of two hours. An independent equatorial stand for this instrument is very desirable, but cannot be had

at present. Plates 8 x 10 are used, which correspond to about 16 by 20 degrees. The definition is good over the central 10 or 11 degrees. E. S. H.

OCCULTATION OF *JUPITER*, 1889, SEPTEMBER 3.

PHENOMENON OBSERVED.	INITIALS OF THE OBSERVER. — LICK OBSERVATORY MEAN TIME.			
	J. E. K.	E. E. B.	C. B. H.	A. O. L.
	h. m. s.	m. s.	m. s.	m. s.
First Contact of *Jupiter*	5 25 39.1	25 41.3	25 43.5*	25 41.6
Second Contact of *Jupiter*..	5 27 50.7	27 47.3	27 47.8	27 43.9
Reappearance of Satellite II.	6 11 33 ±	......	......	......
Reappearance of Satellite IV.	6 16 46.2	......	......	......
Third Contact of *Jupiter* ...	6 19 17.2	......	......	19 26.2
Fourth Contact of *Jupiter*...	6 21 39 ±	21 38.3::	21 39.5::	21 32.2
Reappearance of Satellite I..	6 23 12.8	23 15.7::	23 16.0†	......
(Instrument employed)	*36-inch Tel.*	*12-inch Tel.*	*6½-in. Tel.*	*Comet seeker.*

OBSERVERS' NOTES.—* 3-5 secs. late; † 2-3 secs. late.

Mr. SCHAEBERLE obtained several photographs of the Moon and *Jupiter* after IVth Contact.

Observers; Mr. KEELER = J. E. K.; Mr. BARNARD = E. E. B.; Mr. HILL = C. B. H.; Mr. LEUSCHNER = A. O. L.

These observations have been printed *in extenso* in the *Astronomical Journal*, Vol. 9, page 84 *et seq.*

EXAMINATION OF STELLAR PHOTOGRAPHS.

If it is desired to obtain *all* the information which can be had from a given negative, it is necessary to make a positive copy of it on glass, and to examine both negative and positive independently. Each presents a different set of contrasts. The negative will show the empty spaces and lanes between stars; the positive will show the arrangement of the stars themselves. It is only by examining both that *all* the information can be had from a given exposure. This is certainly true for stellar photographs, and it is even more important in regard to photographs of surfaces,—as nebulæ, the corona, etc. It should also be remembered that no single negative can establish the existence of a new nebula. At least two are required.

Experiments by Mr. BARNARD have shown that many features may be brought out by the simple device of copying the whole of an 8 × 10 plate on a plate of 3¼ × 4¼ inches. This process is analogous to the automatic one by which a person places a picture to be viewed at an appropriate distance for seeing the particular details he wishes to examine. Enlargements of negatives are sometimes serviceable, also. These simple precautions are worth mentioning, as they help to emphasize a fundamental point, namely,—that it is far more important to extract all possible information from a few photographs, than to make large collections of negatives without sufficiently examining each of them. E. S. H.

REVIEW OF THE EARLY NUMBERS OF THE *PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC.*

The *Vierteljahrsschrift* of the German Astronomical Society (Vol. 24, 1889, p. 210) has a very friendly review of the Nos. 1 and 2 of our own *Publications*, written by Professor E. SCHOENFELD, Director of the Observatory of Bonn. The last paragraph is: "The Reviewer has no right to speak in this place in the name of the *Astronomische Gesellschaft;* but, in his own name and in that of other members, he expresses a hearty greeting to the new Society which has been founded on the Coast of the Pacific Ocean and wishes for it all success and prosperity."

It will be gratifying to our members to know of this early and courteous recognition of our modest beginnings. E. S. H.

NOTE ON THE CORONA OF JANUARY 1, 1889.

Professor TACCHINI has a note in the *Atti della R. Accademia dei Lincei* 1889, page 472, on the corona as shown in a positive-copy on glass of one of Mr. BARNARD's negatives. The corona extends, he says, from $+64°$ to $-68°$ on the west limb of the Sun, and from $+53°$ to $-68°$ on the east limb. These are about the limits of the zone of the maximum frequency of protuberances defined by Professor TACCHINI's own observations. Two of the protuberances of the photograph were observed at Rome and at Palermo. The other protuberances shown on the photograph were not seen by the spectroscope, and Professor TACCHINI surmises that they belong to the class of *white* protuberances discovered by him at the eclipses of 1883 and 1886. This surmise is completely corroborated by

the observations of Professor SWIFT (L. O. Eclipse Report, 1889, page 203). E. S. H.

ZENOGRAPHICAL FRAGMENTS.

The Motions and Changes of the Markings on Jupiter, during 1886–7.

Under this title Mr. A. STANLEY WILLIAMS, F. R. A. S., has printed a handsome octavo volume, of 118 pages and nine carefully executed plates, which gives the results of his own observations during 1886–7 with a 6½ inch reflecting telescope (power 170). The work consists of seven sections, as follows: Section I treats of the instrument and the methods of observation (usually transits over the central meridian, 312 of which were observed); II treats of the construction of the chart of the markings on *Jupiter* (which gives the relative positions of all the spots from all the observations, reduced to the positions which they would have occupied had every observation been made April 21, 1887, the date of opposition); III speaks of the general arrangement of the belts, and gives an excellent system of nomenclature for the various separate features; IV, by far the longest section, presents the observations of the different spots in a most convenient form; V gives a summary of rotation periods in different Jovian latitudes; VI relates to the different altitudes (in *Jupiter's* atmosphere) of the different features; while VII treats of the repellant influence apparently exercised by the Red Spot on markings in its neighborhood.

This work deserves an extended notice, which cannot be given here; but it should not be allowed to pass without remark, since it affords an admirable example of just the kind of work which amateur observers can prosecute with great success. Its author (a professional man, constantly occupied) has chosen a definite problem, suitable to his instrumental equipment, and by dint of clear conceptions of the nature of the problem to be solved and of persevering observations in his leisure moments, has produced a work of lasting value. It appears that this volume is to be followed by others on the same subject from the same hand. It can be obtained from MITCHELL & HUGHES, publishers, 140 Wardour street, London. The price is not stated. E. S. H.

ACCOMMODATION FOR VISITORS TO THE OBSERVATORY.

In order to accommodate visitors to the Observatory on the public evenings, a continuous *bench*, long enough to seat one hundred

persons, has been built on the east, south and west sides of the upper gallery of the large dome. As we sometimes have as many as two hundred and fifty visitors to the Observatory during one of our public nights, this addition has become necessary.

The Gundlach Optical Co., of Rochester, N. Y., is making a low-power eye-piece with a large field—something like half a degree—for the use of visitors who come to see the Moon. Such an eye-piece will show enough of the lunar surface to make a *picture* with a background of sky, which is what is really needed to convey the effect. The eye-pieces used in the regular astronomical observations have fields of view of hardly more than 10′ of arc, and, hence, only serve to show a limited portion of the Moon's surface—less than one-tenth, usually. As the image of the Moon in the large telescope is 6.51 inches in diameter, it follows that the field lens of the new eye-piece must be of about the same dimensions. It will be useful in real work also, for objects like nebulæ and comets, where a large field and full contrast are required. E. S. H.

American Equatorial Mountings on Sale in Berlin.

The Observatory has lately received the price-list of Th. Wegener of Berlin. So far as I have examined it, the instruments appear to be well-designed. It is not for this reason that it is mentioned, but because, on page 6, there is given a full-page wood-cut of the equatorial telescope and mounting of the Observatory of Beloit College, Wisconsin. This admirable mounting was made by Warner & Swasey, of Cleveland, from their own designs, and it is an excellent model to follow. It would have been more straightforward for Herr Wegener to have made some acknowledgment of the source from which he derived his model. His wood-cut has no title, and conveys the impression that the design was made by him. Messrs. Warner & Swasey have, however, no cause to complain. Imitation is the sincerest flattery. I can heartily recommend the design of the mounting which Herr Wegener proposes to make. E. S. H.

Notes on Double Stars.

The Herschel companion to ψ^1 *Aquarii* is shown in the 36-inch telescope to be a very close double star. From a single measure the distance appears to be less than 0″.15, and, of course, it is a different object, even in a large refractor. This companion has the same proper motion as the large star, and the relative change is

practically nothing since the measures of STRUVE, in 1836, when the distance was 49″.63 in the position-angle of 312°.2.

Prof. HOUGH found the neighboring star ψ^3 (95) *Aquarii* double, with the Chicago 18½-inch refractor, in 1884, the companion being eleventh magnitude, at a distance of a little more than 1″. Last year this was noted independently here with the 12-inch, and measured on three nights, the result being substantially the same as the single measure by HOUGH in 1884. In the course of the observations given above, this star was looked at with the 36-inch on two or three nights, but there was not the faintest trace of the companion. I am wholly unable to account for this failure, as there was apparently no change in the preceding four years. It should be carefully watched hereafter.

The sixth magnitude star, 44 *Cassiopeiæ*, has a minute attendant, hitherto unseen, at a distance of 1″.7 from the principal star.

Several new pairs have been found in the *Pleiades*, one of them following *Alcyone* 64ˢ and about 4′ north. This is a difficult pair, as the distance is only 0″.3, and the components below the ninth magnitude. Another new pair, still more difficult, is 55ˢ following *Pleione* (28 *Tauri*). The distance of this pair is about 0″.4, but the components are only 11½ magnitude.

Since the time of HERSCHEL, 67 *Ophiuchi* has been known as a wide double star (54″). The large telescope shows a very faint star at a distance of 6″.8.

The star D. M. 63°, 1618, has a very small companion at a distance of 4″.3. The principal star is brighter than sixth magnitude, but is strangely wanting in nearly all of the star catalogues covering this part of the heavens. It is not in the B. A. C., Radcliffe (1 and 2), Lalande, Argelander U. N., Heis, Piazzi, Bradley, Romberg, AOe, Grant, D'Agelet, Armagh, Yarnall, Bonn observations. In fact, it is found only in the D. M. and Rumker (No. 8289), the magnitudes being 5.9 and 5.6, respectively. In the Harvard Photometry the magnitude is 5.82. In observing it here as a double star the magnitude was estimated 5.8. It does not appear to be variable, and is probably a rare example of star catalogue omissions. The attention of meridian observers is called to this object.*

The double star, Σ 2816, consists of a sixth magnitude primary, and two 7½ m. companions with distances from the larger star of about 12″ and 20″, respectively. These stars have remained rela-

* This star will be observed by Professor SCHAEBERLE with the L. O. meridian circle.—E. S. H.

tively fixed since 1832. The large telescope shows a minute companion within 1".5 of the large star.

The fifth magnitude star, 2 *Andromedæ*, is a very close and difficult pair, the distance being only 0".8, and the components quite unequal. This was suspected with the 12-inch, and verified and measured with the 36-inch.

HERSCHEL noted a ninth magnitude companion to *α Cassiopeiæ* at a distance of 63". The large telescope shows a very faint star at a distance of 17".5.

The distance of the close pair in *γ Andromedæ* (*OΣ* 38) is now less than 0".1. It is very difficult, and the best conditions are necessary to see the elongation at all with the large telescope.

The binary star, 7 *Tauri*, has been rapidly changing. The distance now is 0".30.

The large refractor fails to show any third star in the system of 70 *Ophiuchi*, and both components are single with all powers. At one time 72 *Ophiuchi* was thought to be double (*OΣ* 342), but no companion can be seen here. S. W. B.

NOTES ON STELLAR SPECTRA.

The spectra of the following stars (among many others) have been examined here during the past summer with a small spectroscope attached to the 36-inch equatorial, and in response to inquiries which have been made, I give below a preliminary statement of the results. The spectroscope which was used has no measuring apparatus, and the positions of lines are merely eye estimates.

γ Cassiopeiæ. This star is the most conspicuous example of VOGEL's class I *c*, and remarkable changes in the bright lines in its spectrum have been observed by VON KONKOLY, VON GOTHARD and others. I have therefore examined it frequently, but, so far, no changes have been seen. The C and F lines are brilliant, narrow and sharp; Hγ, in the violet, is seen with some difficulty. The green is full of very fine, delicate dark lines, seen only under good atmospheric conditions, the *b* group being somewhat more prominent than the others. There is also an appearance of faint bright lines in the green, which may be due to the actual existence of bright lines, or, perhaps, to spaces between the fine dark lines just mentioned, seeming bright by contrast. It is difficult to decide on this point. There are in all eight or ten such places. Somewhat nearer to C than to the estimated position of D is a fairly prominent dark band,

or, more probably, group of fine lines. Not the slightest trace of either dark or bright lines can be seen in the vicinity of D. The continuous spectrum close to the bright hydrogen lines appears somewhat darker than it does elsewhere, but this I have considered to be the effect of contrast.

U Cygni. This is a very red star, with a spectrum described by DUNÉR as III*b*. When examined with the 36-inch refractor it was of about the tenth magnitude, and the spectrum was dim, but the zones in the lower part could be distinguished. The blue was excessively faint. There was no appearance of bright lines.

V Cygni is also a very red star, and when examined with the spectroscope was of about the same brightness as *U Cygni.* Its spectrum is described by DUNÉR as III*b*! The sky was remarkably smoky when observations were made here, and the spectrum was dim, but at three places in the yellow and green shone with such comparative brightness that these places appeared like bright lines. The brightest was the more refrangible yellow line. It is possible that these lines may be the edges of the usual zones of class III*b*, as DUNÉR says the yellow and green zones are very bright, but the appearance was more like that of bright lines.

D. M. 43°, No. 3571. This is a star recently found by Prof. PICKERING, by the aid of photography (A. N. 2912), to belong to class II*b*. It is much like the other stars of this class found by Prof. PICKERING and by WOLF and RAYET. The faint spectrum connecting the principal bright lines in the spectra of these stars appears to be continuous with a small instrument, but with the 36-inch refractor is seen to be an extremely complicated range of absorption bands and faint bright lines. The above star differs from others that I have examined in the unusual broadness and diffuseness of these faint bands. J. E. K.

"AN IMPROVED ASTRONOMICAL MIRROR."

A device for constructing large telescope mirrors, which has recently been patented (at an expense of $60), is described under the above title in the *Scientific American* for September 7, 1889. The mirror is a flat, circular disc of metal, supported around its circumference by a flange or shoulder on the cell. Through a hole in its centre passes a bolt, and by turning a nut on the outside of the cell, the mirror is "buckled" into shape. The inventor has omitted to mention that by carrying the motion of the nut to a convenient position

near the eye-piece a ready adjustment of the focus will be obtained. This method has the great advantages of simplicity and cheapness; its defects will be ascertained by the inventor when he comes to try it.

J. E. K.

Observations on the near approach of Mars and Saturn on September 19, 1889.

The eastern sky was thick with haze when the two planets rose, and they were not visible until a considerable altitude was attained. At about 4 A. M. they could be seen dimly with the naked eye; *Mars*, small and insignificant, slightly east of *Saturn*. As soon as the images were at all measurable, I made a series of micrometrical observations of the two for position angle and distance, and for differences of right ascension and declination, using the 12-inch equatorial.

Following are the measures which are corrected for refraction in distance and in the $\Delta\,\delta$ and $\Delta\,\alpha$; the times being Mt. Hamilton mean time:

		d. h. m. s.	
1889.	Sept.	19 16 16 39.	Position angle of *Mars*, 101°.0 (3).
"	"	19 16 24 24.	Dist. betw'n outer limbs of *Mars* and *Saturn*, 356".1 (3).
"	"	19 16 29 14.	" " nearer " " " " 342".3 (3).
	"	19 16 34 19.	" " center and center, 358".8 (3).
"	"	19 16 39 49.	Position angle of *Mars*, 101°.8 (4).
"	"	19 17 36 29.*	$\Delta\,\delta$ ♂—♄ $-1'\ 39''.2$ (5) apparent.
"	"	19 17 45 49.*	$\Delta\,\alpha$ ♂—♄ $-0^m\ 29^s.91$ (11) apparent.

The most striking feature was when the two planets were fading from the advent of daylight. At the approach of day *Saturn* assumed a pale, ashy hue, with a slight tinge of yellow, while *Mars* retained its lustre in a surprising manner, being of a strong orange yellow in color; its north polar cap stood out strikingly towards the close of the observations, a dark marking being also visible near the middle of the disc. *Saturn* ceased to be visible in the telescope at 18h. 6m., the last glimpse being had a few seconds earlier. At this time *Mars* was easily conspicuous, the sun being 5° or 6° high and the sky pretty thick. At 18h. 10m. *Mars* began to grow pale. At 18h. 25m. it was still visible but very pale and easily lost in the field, though it could have been followed for some time longer. By the time the

* These times are for the bisection of *Mars*.

planets were high enough to observe with the large telescope they had separated too far to be brought into the field of view of the largest eye-piece. E. E. B.

Mt. Hamilton, Sept. 20th, 1889.

The Uses of Trails of Stars in Measurements of Position or of Brightness.

Photographs of star groups may be made for either one of three important objects. They may serve — (*a*) to give a picture merely; (*b*) for measurement of the relative positions of the stars of the group; or, (*c*) for measurement of the photographic magnitudes of the stars of the group. For the first purpose the stars must be photographed as points or *dots*. Such dots may also be used for the purposes *b* and *c*. For the purposes *b* and *c* it will often be very advantageous to employ *trails* instead of *dots*. The difference of declination of two stars, A and B, can be more accurately determined from measures made of the distance apart of their *trails* than from measures of the distance of the corresponding *dots*; just as a star can be more accurately bisected in declination by a Z. D. micrometer than in R. A. by a fixed thread. Hence the use of trails in R. A. If now we can produce trails in declination, a corresponding advantage can be had for measures of differences of R. A. The negative plate of the great equatorial is to be mounted on a compound slide-rest. The upper slide-rest which carries the plate has a motion in any desired direction (usually in R. A.), and the lower slide-rest, which carries both plate and upper rest, has a motion at right angles to the direction for the upper slide.

If a clock-work motion is attached to the lower slide, this slide can be moved in declination (say) for a certain distance (only). It will finally come to the end of its run. Suppose the telescope at rest, the objective covered and the lower slide-rest moving in declination. If an exposure is now made, we shall have trails suitable for measuring differences of R. A. After a few minutes, the lower slide comes to the end of its run. Trails in R. A. are now produced, which are suitable for measures of differences of declination.

The direction of motion of the lower slide may be ordered in *any* desired position angle. Thus we may choose the direction of the first set of trails so as to be most advantageous for the subsequent measures. The second set of trails will always be in R. A. The angle between the first and second directions will define the

position angle of the first trails. It is believed that this simple method will have important bearings on the determination of stellar parallax by photography, a research for which the great equatorial is especially fitted.

Trails may also be used to determine the magnitudes of the stars. The blackening of the plate is proportional to the photographic magnitude of the star and to the star's rate of motion on the plate (and to other things, also).

Two stars at different declinations will move at different rates on the plate and hence will produce trails of different intensity. A (theoretical) correction for the different rates of motion can be made and the measures of the relative intensities of the trails can be taken as measures of the relative magnitudes of the stars. This method has been extensively used by the Harvard College Observatory.

I will not here discuss the objections to the method, but will simply show how all objections can be overcome by adopting an ingenious proposal made by Professor SCHAEBERLE. His suggestion is to photograph the trails of all stars on a plate moving in declination at the same rate that an equatorial star moves in R. A. All trails will then have the same exposure. The rate of the clock which drives the plate in declination can be tested at any time by photographing *both* trails (R. A. and Dec.) of the same equatorial star.

It appears to me that a photometry of all stars sufficiently bright to give such trails should be made by this method. For fainter stars the method described by Professor SCHAEBERLE (*Publ. Ast. Soc. Pacific*, No. 4) should be employed. E. S. H.

LICK OBSERVATORY, July 15, 1889.

Minutes of the Meeting of the Board of Directors, held September 28, 1889, at the Lick Observatory.

A quorum was present.

The report of the Treasurer was received and ordered on file.

The printing of a circular of information was authorized.

Hon. R. W. Waterman, Governor of California; Henry Lord Boulton, Esq., Caracas, Venezuela; Mrs. Anna Palmer Draper, New York City, were duly elected as life members of the Society.

It was *Resolved*, That the design for the Society's diploma recommended by the Committee be adopted, and that 500 copies of it be printed by Messrs. Britton & Rey.

Mr. Pierson reported that the Society had been incorporated on August 28, 1889.

The thanks of the Board of Directors were offered to Mr. Pierson for his kind services in the matter of incorporating the Society, and also to Mr. Knox, notary. The fees to State officers were ordered paid.

It was ordered that the Secretary in San Francisco be furnished with a revolving fund of $10 for the payment of petty bills. Adjourned.

Minutes of the Meeting of the Astronomical Society of the Pacific, held September 28, 1889, at the Lick Observatory.

[Prepared by the Secretaries for Publication.]

The minutes of the meeting of July 27 were read and approved.

A list of presents to the Society was read, and thanks were returned to the donors.

The following persons were elected to membership (the names of life-members, duly elected by the Board of Directors, are marked with a star (*):

Henry Lord Boulton, F. R. A. S.*	Caracas, Venezuela.
Rev. A. L. Brewer, ...	San Mateo, Cal.
George W. Beaver, ...	418 California Street, San Francisco, Cal.
Hon. John L. Beard, ...	Centreville, Alameda Co., Cal.
A. J. Burnham, ...	Lick Observatory, Cal.
Mrs. Anna Palmer Draper,* .	271 Madison Avenue, New York City.
W. E. Downs, ...	Berkeley, Cal.
S. J. Cunningham, ...	Swarthmore College, Delaware Co., Penn.
Prof. Geo. C. Edwards, . . .	Berkeley, Cal.
Prof. T. C. George, ...	University of the Pacific, San José, Cal.
Prof. Alfred Higbie, ...	University of the Pacific, San José, Cal.
Dr. J. C. Hawver, ...	Auburn, Cal.
Hon. W. H. Jordan, ...	328 Montgomery Street, San Francisco, Cal.
Prof. Josiah Keep, ...	Mills College, Alameda Co., Cal.
Miss Laura Kimber, ...	Occidental Hotel, San Francisco, Cal.
Dr. A. Liliencrantz, ...	1459 Telegraph Avenue, Oakland, Cal.
F. G. Montealegre, ...	230 California Street, San Francisco, Cal.
President C. C. Stratton, . . .	Mills College, Alameda Co., Cal.
Frederick C. Terry, ...	529 Commercial Street, San Francisco, Cal.
Otto von Geldern, ...	1905 Polk Street, San Francisco, Cal.
Rev. J. H. Wyeth, ...	Oakland, Cal.
Hon. R. W. Waterman,* . . .	Sacramento, Cal.
E. C. Winchell, ...	1214 Grove Street, Oakland, Cal.
Edward B. Young, ...	430 Montgomery Street, San Francisco, Cal.

The design for the Society's diploma, which was recommended by the Committee and has been adopted by the Board of Directors, was exhibited to the meeting.

(Extract from the Report of the Committee on the Diploma.)

"A design for this diploma was prepared by the Committee and sent to Mr. P. R. CALVERT of Nashville, who has made the finished drawing.

"As the Astronomical Society of the Pacific owes its origin to the association of amateur and professional astronomers in the observation of the Total Solar Eclipse of January 1, 1889, it was thought appropriate to give a chief position in the diploma of the Society to the Sun's Corona as then displayed. Accordingly, the centre of the upper panel contains the Sun, the Moon and the Corona of January, 1889. To the left and right of this are the symbols of the eight major planets. The twelve medallions of the lower panel include the twelve Zodiacal signs, copied from the beautiful designs of Mr. VEDDER. The right hand panels represent first, the great comet of 1858, and second, the configuration of the Constellation of Orion. The stars of this constellation may stand for the stellar universe; while they also remind us that the central star of the sword-handle is the nucleus of the grandest of all the nebulæ. The drawing of the Muse of Astronomy—*Urania*—in the left-hand panel is copied from the antique statue of the Vatican. The national coat of arms in the upper left-hand panel designates the country in which the Society has its seat, and to which the work of our members should bring increasing honor as time goes on."

E. S. HOLDEN, E. E. BARNARD, W. B. TYLER, *Committee.*

It was announced that Mr. DONOHOE had secured very satisfactory designs for the Comet Medal from M. DUBOIS in Paris, and that the dies were now making.

The Society was also notified that Messrs. BURNHAM and SCHAEBERLE were to leave California September 29th or 30th for South America, on the expedition to observe the Total Eclipse of December 21st. Thanks to the generosity of Mr. CROCKER, the expedition is completely equipped, and, barring bad weather, is sure of success.

The U. S. Government will send an expedition in the U. S. S. *Pensacola*. Five thousand dollars has been appropriated to cover the expenses. The expedition is under Professor TODD. The vessel will touch at St. Paul de Loanda, and from thence two parties will, it is said, separate and go to points on the Coanza River.

The English expedition to South America under Rev. Father S. J. PERRY, F. R. S., will take station at Salute I., near Cayenne. Mr. TAYLOR, F. R. A. S., goes to St. Paul de Loanda. Each of these expeditions has the same programme and twin instruments, viz: an ABNEY 4-inch photographic lens and a 20-inch reflector of 45 inches focus. It is hoped to get sixteen pictures at each station. No spectroscopic work is to be attempted. Miss BROWN and Miss JEFFERYS, who observed the eclipse of 1887 in Russia, expect to observe that of next December in Trinidad. H. M. S. *Comus* is placed at the disposal of the English expeditions by the British Admiralty.

It is to be regretted that the Lick Observatory Expedition is (apparently) the only one provided with a lens of more than 45-inch focus. The experience of last January seems to have shown that the solar images from lenses of less than 60 or 70 inches focus are too small to show much detail in the *inner* corona.

The papers presented were:

On the Companions to BROOKS' Comet (July 23, 1889) discovered at the Lick Observatory, by E. E. BARNARD.

Drawings of *Jupiter* made with the 26-inch Equatorial at Washington during 1875, by E. S. HOLDEN.

Drawings of *Jupiter* made with a 5-inch Equatorial at Nashville during the years 1879–1883, by E. E. BARNARD.

(The drawings of *Jupiter* made by Mr. KEELER with the 36-inch Equatorial during the present opposition were not exhibited for lack of time.)

On the Establishment of a Standard Meridian Line for Santa Clara County, California, by JAMES E. KEELER.

Occultations of Stars by the Moon, by A. O. LEUSCHNER.

Conjunction of *Mars* and *Saturn*, September 20, 1889, by W. E. DOWNS.

On the Photographic Brightness of the Fixed Stars, by J. M. SCHAEBERLE.

These papers will be printed in full or in abstract in numbers 4 and 5 of the Publications.

The Society then adjourned to meet at its rooms, 408 California Street, San Francisco, on November 30, 1889.

OFFICERS OF THE SOCIETY.

EDWARD S. HOLDEN (Lick Observatory), - - - - - *President*
WM. M. PIERSON (76 Nevada Block, S. F.), - - - } *Vice-Presidents*
W. H. LOWDEN (213 Sansome Street, S. F.), - - }
FRANK SOULÉ (Students' Observatory, Berkeley), - - }
CHAS. BURCKHALTER (Chabot Observatory, Oakland), - } *Secretaries*
J. M. SCHAEBERLE (Lick Observatory), - - - - }
E. J. MOLERA (850 Van Ness Avenue, S. F.), - - - *Treasurer*

Board of Directors — Messrs. ALVORD, BOERICKE, BURCKHALTER, GIBBS, GRANT, HOLDEN, LOWDEN, MOLERA, PIERSON, SCHAEBERLE, SOULÉ.

Finance Committee—Messrs. GIBBS, PIERSON, MOLERA.

Committee on Publication—Messrs. DEWEY, TREAT, ZIEL.

Committee on the Comet Medal — Messrs. HOLDEN (*ex-officio*), SCHAEBERLE, BURCKHALTER.

NOTICE.

Members are requested to preserve the copies of the Publications of the Society as sent to them. At certain intervals a title page and index of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with Mr. BURCKHALTER, at the rooms of the Society, 408 California Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

No. 5. SAN FRANCISCO, CALIFORNIA, NOVEMBER 30, 1889.

OBSERVATIONS OF *JUPITER* WITH A FIVE-INCH REFRACTOR, DURING THE YEARS 1879–1886.

BY E. E. BARNARD.

During the years 1879 and 1880 I was constantly employed in the daytime with my business duties; but every possible opportunity was used in astronomical observations at night. The latter part of 1879 and the major part of 1880 were devoted to an extended series of observations and drawings of *Jupiter*.

These observations were made at Nashville, Tennessee, ($\lambda = + 0^h 39^m.0$; $\phi = + 36° 10'$), and before I was connected with the Vanderbilt University Observatory.

The telescope was a five-inch refractor, mounted on a portable tripod, without a driving clock. A magnifying power of 173 diameters was nearly always employed—the instability of the mounting preventing the use of a much higher power. A right-angled prism was used with the eye-piece. This shows the planet reversed, but not inverted. In sketching, a small wooden box or desk was used, with a glass in the top, on which the paper was laid. A faint illumination from below, through the sketching paper, was obtained from the reflected light of a candle. By this means I could sit with the desk on my knees and compare the telescopic image directly with the drawing.

The drawings were very carefully made, and faithfully show the markings as they appeared upon the planet at the time of observation. Professor HOLDEN has lately seen these drawings, and suggested that I collect them together and prepare them for reproduction by photo-lithography. I have, therefore, selected forty-five of them as fairly representing the phenomena of *Jupiter* during the period of observation, and they are reproduced in Plates I, II, III, IV, following. Constant reference should be made to the plates by the reader. In these plates the top of each drawing is north; the bottom is south;

the right-hand side is east, or following; the left-hand side is west, or preceding.

During the observations the usual appearance of the planet was about as follows: Around the equatorial regions was a broad band or belt, which could really be said to be two belts; for it was always divided longitudinally by a sinuous, lighter portion, which was sometimes much broken by diffusions from the belts and by cloud like forms. In the observations, I have considered this great belt as two, and have called the parts, respectively, the north and the south equatorial belts, or, collectively, the equatorial belt. Considered as one, the belt was about one-fifth the polar diameter of the planet in width.

Just south of the equatorial belt was situated the Great Red Spot, covering an area of over two hundred million square miles—greater than the entire surface of our earth.

On the inner part of the south equatorial belt was frequently seen a brilliant white spot, which had a very strong proper motion with reference to the Red Spot.

To the north of the equator were situated three narrow lines or belts. I have designated these as the first, second and third linear belts. The third was usually the border of the north polar cap, while the first became the scene of remarkable changes about the 1st of November, 1880.

What principally attracted my attention to the planet was the appearance of the Great Red Spot. The early history of this object seems to be rather obscure, but it was certainly seen as early as July, 1878, by Professor PRITCHETT, at Glasgow, Missouri, and was probably seen at intervals as early as 1870.

It was first seen by me in the early morning of August 3, 1879. I had heard nothing of it; and while observing and sketching *Jupiter* it came into view around the following limb, and was so remarkable in form and color that I was at once struck with its appearance. On this date the form of the spot was different from what it was at any of my subsequent observations. While the south edge of the spot was nearly straight and the following end blunt, the north edge tapered towards the preceding end, strikingly like the drawing by TROUVELOT in the *Observatory* for April, 1879 (p. 411).

It will be seen that my drawings nearly all show some phase of the Red Spot. I have so selected them because it was the principal object of interest with a small telescope, and therefore received the most attention. Though the Red Spot was watched carefully, I never saw any details on its surface until the latter part of the obser-

vations, when a whitish cloud formed upon it. Changes were sometimes seen, however, in the form of the spot. These were confined to the ends, which occasionally appeared rounded, and, again, were very much pointed, or cigar-shaped. Faint trails were frequently seen running from one end or the other of the spot, and sometimes from both ends at the same time; the most persistent of these was the trail from the preceding end.

One of the most interesting features of the Great Spot was the repulsion it seemed to exert upon adjacent markings on the planet. For a time it was surrounded by a sea of light that completely encircled it for a distance of three or four thousand miles (see drawing of October 3, 1879), and which appeared as a visible barrier against the approach of any spot or marking. So manifest was this repellant force that, as early in the observations as 1879, I called attention to it in the *English Mechanic* (Vol. 30, p. 166).

There was, however, one striking exception to this general rule: In July, 1880, a dense, smoky shading was seen apparently attached to the south side of the Red Spot, extending to the south preceding, and covering an area but little less than the Great Spot itself. This eventually passed the Red Spot, and, having a shorter period, soon left it far behind, and finally became squeezed out into a short longitudinal belt or spot, some twenty-five or thirty thousand miles long. Two white belts, one on each side, seemed to compress it into a definite form, that now extended east and west, instead of southwest and northeast, its primitive direction.

During the observations, a great number of estimates were made of the instant that the Great Spot was in transit across the central meridian of the disc of *Jupiter*. In discussing his micrometer measures of such transits from June to December, 1880, on thirty-one days, Prof. HOUGH says that his observations "gave for the mean error of a single pair of measures $\pm$ 0^{m}.9, and for the average mean probable error for any day, $\pm$ 0^{m}.4, on the observed transit of the Red Spot over the central meridian," and further remarks: "It may be inferred from these results that the use of a micrometer is infinitely preferable to any method of estimation." Among the observations of the Red Spot I have forty-four complete and carefully estimated transits—that is, observations of the preceding end, middle, and following end of the spot. Twenty-one of these are from a single but careful estimate of each phase. These give the probable error of a transit of the center from the mean of the three observations = $\pm$ 1^{m}.0. In twenty-three of these transits three estimations were

made of each phase; from these I get for the transit of the middle from the mean of the nine observations the error of the transit, $= \pm 0^m.7$. These values are comparable with the best micrometer measures. It is evident that they should be so. The Red Spot moves through an angle of about $0°.6$ in 1^m. At transit this amounts to a change of distance from the limb of about $0''.2$. It is clear, that with a five-inch telescope the position of the spot could not have been fixed more closely with a micrometer (even if I had been provided with one, which was not the case) than it was by the method of transits. I think the sole advantage of micrometer measures in a case of this kind is that they can be made *near* the transit, thus saving time by not having to wait for special phases, and that they can be repeated until the accidental error of the result is reduced to a small quantity.

I have inserted the above comparisons to show what accuracy may be obtained by carefully made estimates, and as an encouragement to those who have not all the accurate appliances of an observatory to work with.

During the observations, which frequently extended over an interval before the appearance of the Red Spot at the following limb and until after it had disappeared at the preceding limb, I several times noted the moment when the first trace of the Red Spot could be seen at the *f.* limb. The mean of seven such observations, compared with the observed transit of the center of the spot, gave the interval $2^h\ 1^m$ from the first trace of the *p.* end of the Red Spot at the *f.* limb, until the center of the spot was in transit. This gives $1^h 36^m$ as the time that a mark of the same distinctness as the Red Spot, and at the same distance from the equator, could be seen before its transit; $3^h\ 12^m$ is, therefore, the total duration of visibility of *any* point of the Red Spot during a rotation. Thus the spot could never be altogether invisible through rotation for a greater interval than $5^h 53^m$ from the time the *f.* end disappeared at the *p.* limb until the *p.* end reappeared at the *f.* limb. The mean of two estimates gave $1^h 9^m$ as the interval between the time when the spot was clearly seen free within the *f.* limb and the time of transit of its center. Slight variations in the tint and depth of color of the spot were noticed, and it was frequently contrasted with some portion of the equatorial belt; but as the belt itself was probably subject to a far greater change in depth and color than the Red Spot, such a comparison would not be very conclusive proof of change.

It would take up too much space to give the observations, even in

an abbreviated form, so I shall briefly summarize the most important points:

The Color of the Red Spot.

1879. Aug. 2, it is described as of the color of red-hot iron.

1880. July 11, a clear, darkish Indian red, brighter in color than equatorial belt; July 24, a clearer red than equatorial belt; July 29, a light Indian red, the belts a duller red; Aug. 16, a brick-dust color—same tint as north equatorial belt; Sept. 14, a lighter red, very much lighter than north belt; Sept. 16, a brick red, more strongly marked than the north band; Sept. 25, a deep brick-dust color; Sept. 30, a distinct red, the equatorial bands a heavier red; Oct. 7, a redder color than the belts; Oct. 13, a heavy red, clear and sharp; Oct. 20, a light, clear red; Nov. 1, a pale red; Nov. 3, a deep brick-dust color; Nov. 11, a solid red, well outlined; Nov. 20, a little less deep in color, but very much redder than the belts.

1881. Jan. 7, not so well defined at edges, but a deeper tint at the middle; July 2, a pale light red; July 9, the spot is even of a deeper tint than last year; Oct. 31, lightish red.

1882. Jan. 23, faintish red, very pale.

1885. April 25, it is very faint—quite difficult to observe—a very pale red; April 28, it is very well seen, and is clearly outlined all round; May 12, very faint; May 15, fairly distinct, probably a white mass superposed on it.

1886. April 8, a long white cloud clearly seen on the Red Spot; April 22, very faint, a whitish strip of cloud on it, north of middle.

Trails from the Ends of the Red Spot.

Faint reddish trails were recorded on the following dates:

1879. Oct. 3, faint trail from following end.

1880. July 11, faint trail from preceding end; July 18, faint trail from each end; Aug. 16, faint trail from each end; Aug. 30, faint trail from each end; Sept. 16, faint trail from each end; Nov. 18, faint trail from preceding end; Nov. 20, faint trail from preceding end.

1886. Nov. 5, faint trail from preceding end.

These usually were about 2″ or 3″ long.

Size of the Red Spot.

Frequent estimations were made, at the telescope, of the relative size of the Red Spot, on dates extending from July, 1880, to December 14, 1880. Following are the estimations:

Breadth: From twelve estimates of its breadth north and south, it was just perceptibly less than one-half the breadth of the equatorial band = estimate I; while eight estimates made it exactly one half = estimate II. One estimate placed it perceptibly greater than one-half = estimate III.

Length: Sixteen estimates made the length very slightly less than one-third the length of the same parallel of the disc of *Jupiter* = estimate I; while the mean of six other estimates made it 0.32 that distance in length = estimate II.

Distance of North Edge of Spot from South Edge of Belt: Twenty-four estimates of the distance between the north edge of the spot and the south edge of the equatorial belt gave it 0.40 of the width of the spot, with decided and considerable variability (which never, however, exceeded one-half).

Adopting from the *Report* of the Dearborn Observatory for 1882 Professor HOUGH'S micrometer measures of the breadth of the equatorial bands (for a period exactly covering my estimation) as = 7".04, and his value for the radius of the parallel of the center of the Red Spot = 17".94, we have the above estimations expressed in seconds of arc at the distance unity.

BREADTH OF SPOT: Estimate I = very slightly less than 3".5.
Estimate II = 3".5.
Estimate III greater than 3".5.

LENGTH OF SPOT: Estimate I = very slightly less than 12".0.
Estimate II = 11".5.

DISTANCE NORTH EDGE OF SPOT FROM SOUTH EDGE OF BELT: Assuming, with the above estimates, the breadth of spot to equal 3".5, the estimates give the distance above as 1".4.

THE BAY AT THE RED SPOT FORMED BY THE SOUTH EQUATORIAL BELT.

This singular recurring feature of the south equatorial belt is worthy of particular attention. As it seems intimately connected with the Red Spot, it had best be mentioned here. In a drawing published in the *Observatory* for April, 1879 (p. 411), TROUVELOT shows a sharp curvature of the south side of the equatorial belt around the preceding end of the Great Spot, forming, as it were, a bay. He says it had disappeared and reappeared no less than three times in a little over a year, always reappearing at the same place with reference to the Red Spot. This bay, or a similar one, is shown in my drawing of October 3, 1879. It then curved south, following

the Red Spot, the southern limit diffusing very greatly, but sharply terminated where it curved down following the spot. It is shown thus also in a drawing of September 14, 1879. It was wholly absent throughout 1880, the south edge of the equatorial band being perfectly straight all around the planet. The first indication I have of its return is February 4, 1882, (the observations had, however, ceased to be continuous after 1880), when I recorded that the south equatorial band "appeared to blend southwards, following the Red Spot." In 1885, this feature was distinctly marked—the appearance being the same as in 1879, except that its extreme south edge did not blend so much as in that year. Its presence was marked on April 25, May 12, May 15, and, 1866, April 22, when the planet was examined. The absence of other dates indicates only that the region of the Red Spot was not examined, and not that the bay existed only on these dates. At the Lick Observatory I have seen it frequently at the present opposition just as it was in 1879. That this is intimately connected with the forces that produce the Red Spot there is no doubt. In connection with this feature and the Red Spot, I would mention a singular thin red line that sprung out from the south edge of the equatorial band like a spur, and, curving backwards, ran along parallel to the south edge of the equatorial belt for some distance. This is shown in the drawings of 1880, September 18, 28, 30, and October 10. Prof. HOUGH has figured this singular object in a drawing made September 9, 1880, with the 18½-inch refractor, just as I have seen it, except that he does not show it of a red color. (See *Report Dearborn Observatory*, 1882.) It occupied a place near the preceding curve of the bay. Though this spur-line joined the south edge of the equatorial belt, to which it seemed attached, it did not partake of its motion; for throughout its visibility it retained the same position with reference to the Red Spot, showing that its period was the same as that of the spot, while the period of the belt is about $5\frac{1}{2}^{m}$ shorter.

I have already mentioned the smoky shading which, in July, 1880, seemed to be attached to the Red Spot, and which finally passed by it through a more rapid rotation. It is shown on a great many of the drawings. I would specially call attention to those of Pl. I (July 24, 29, August, 16, 17, September 9, 11); Pl. II (September 30, October 7, 10, November 1). The drawing of July 24, 1880, shows a very small spot near transit in the southern hemisphere. This small spot was usually quite hard to see, but was clearly defined and dusky when best seen; it was probably about 4000

miles long and some 2000 miles wide. The remarkable features were its permanency and its slow rotation period. Its period being somewhat less than the Red Spot, it slowly drifted westward from that object, and probably, in course of time, completed a circuit of the planet, which it would do in a little over two years, when it would again be in the region of the Red Spot. It is shown in several of the drawings.

The Equatorial White Spot.

Throughout the entire period of my observations, there was present on the planet a very remarkable White Spot, situated on, or generally imbedded in, the north edge of the south equatorial band. This object was subject to remarkable changes of form and brightness. It required but a few observations to show that it was in rapid motion with reference to the Red Spot. Its period was nearly five and a-half minutes shorter than that of the Great Spot. Its westward drift with reference to that object was about 8° of longitude per day, or about 2430 miles, at every rotation of the planet. This rapid relative motion with reference to the Red Spot would therefore carry it completely around the planet in forty-five days, and a number of such revolutions were actually observed. It required but four days for this swiftly moving body to completely pass the Red Spot, which it soon left far behind, and in twenty-two and one-half days it would be on the opposite side of the planet. I would refer to the drawings of Plate III (November 18, 20, 22 and 23), where one of these passages of the Red Spot is shown. The motion of this object was not perfectly uniform. At times it seemed to slacken its speed, and then to spurt forward again. Among the surprising things about this spot were its great changes, both of form and brightness. At times it became so bright as to glisten like a star. When in this condition it was by far the brightest object on the planet. For a while it would appear as a rather small, inconspicuous, light, oval spot, imbedded in the dark matter of the north edge of the south equatorial band. In this state it would scarcely attract attention. It would next be seen brilliantly white, burying its head in the dusky matter of the belt, with a vast, luminous train streaming backwards along the equatorial regions, like the tail of a comet. Sometimes this train was composed of white, cloud-like balls, that streamed eastward on the planet. After continuing thus for some time, it would seem to have wasted its energies, and would then assume the quiescent state. I have tried to connect these changes of brightness with the changes of motion, but have not been able to do so, though there

is doubtless a relation between them. When at its brightest it seemed to burrow in the south band and plow the matter before it. A long, sinuous rift in the northern part of the north equatorial band had constantly the same relative position to the White Spot, and was perhaps in the same layer of the planet's atmosphere. Probably all the objects in the equatorial regions had the same motion as the White Spot, or were stationary, relative to it. Indeed, the entire belt is revolving around the planet once in forty-five days, relatively to the Red Spot.

I will select a few of the many notes I have on this object and those connected with it:

1880. Aug. 13 (13^h 33^m), a brilliant white spot appearing at the *f.* limb; Aug. 16 (11^h), very white; Aug. 18, bright spot n. f. Red Spot, followed by light, cloudy masses; Aug. 23, the bright spot of the 18th has toned down; Aug. 30, bright; Sept. 10 (10^h 30^m), brilliant, with train; Sept. 15 (9^h 30^m), very bright, with train of white, cloudy masses; Sept. 24 (about 9^h), a bright head, with long, curved stream of white matter following; Sept. 28 (11^h 30^m), bright; Sept. 31 (7^h 33^m), two large white spots about midway the disc, a smaller one between them—they all shine with a very white luster; Nov. 11, a great number of white balls seen near 10^h; Nov. 18, white; Nov. 20, it is more isolated from the other matter—pale white, diffused at edges; Nov. 22, smaller and pale, about the size of Satellite I, but much paler; Nov. 23, it is smaller and paler; Nov. 24 (9^h 20^m), light; Nov. 29, white. When best seen, it is roundish. It seems to push a dark mass in front of it; it is as large as a satellite.

1881. Jan. 7, very bright and well-defined—it keeps the mass of matter pushed up in front of it as before; Aug. 3, a small white spot; Oct. 29, a very bright spot, with luminous and clouded train; Nov. 1, bright, and plowing its way along the equatorial regions; Nov. 12, white and distinct, about the size of a satellite, a clouded train following.

1882. Feb. 4, white—fainter, luminous train.

1886. May 13, white, luminous train.

The above times do not necessarily refer to its transit. These apparitions were doubtless the same object, as they refer to a bright body imbedded in the inner edge of the south band, and just south of the equator. From the comparisons of its size to the satellites, it was probably about two or three thousand miles in diameter. It is shown on the drawings for (Pl. I) Aug. 13, 16, Sept. 10; (Pl. II)

Sept. 24, 28, 30, Nov. 7; (Pl. III) Nov. 18, 22, 23, and (Pl. IV) Nov. 5, 1881.

The Equatorial Belts.

The equatorial belts were subject to many internal changes. These changes, though frequent, are not so great as one would be led to think from examining, say, that region just north of the Great Spot. Part of the changes are due to the continual drift of the belt past the Red Spot; thus every few days presenting an entirely different part of the belt to view from any one standpoint. As an illustration of this, we have only to follow the White Spot in its journey around the planet. I would also refer to (Pl. II) the drawings of September 30 and October 7, where a decided drift of the dusky masses is shown. These belts changed in strength and depth of color. When I first examined the belts, in 1879, the northern one was reddish, while the southern was bluish; the two being separated by a whitish, serpentine division. Though my notes contain frequent reference to the colors of these belts, it will probably be best, considering the limited space, to very briefly state a few of the observations in a general form.

Colors of the Equatorial Belts.

North of the narrow, light rift in the northern part of the north belt, the color was frequently of a deep, rich vermilion, while the rest of the belt towards the equator was of a much lighter red, though at times it became a very deep, darkish red. The south belt remained bluish for a long time, and I first began to call it reddish about the middle of August, 1880. Even in September I have called it a drab color. On September 9, 1880, when the Red Spot was in transit, the north band was a warm purple, while the south one was a cold purple. On October 10, 1880, at 10^h, part of the north band, north of rift, was a dark, heavy red, while the south band was a bluish-gray, mixed with red; while on October 13, at 8^h-9^h, they were both a deep red. On October 10, 1881, both sides of the belt were reddish, while the inside was bluish.

Forms in the Equatorial Bands, etc.

The belts were usually clearly and sharply defined at their polar edges and perfectly straight. The peculiar disturbances to which they were subject were confined to their inner edges or to parts near the equator. Besides the famous White Spot that has been mentioned, there were sometimes the most exquisitely beautiful forms at the equa-

tor. These came and went—at times filling the interior of the great belt with dusky, cloud-like forms and softly delicate plumes that were very transitory. At times the belts appeared as one, being completely filled in with one solid tint. Such was the case, 1880, September 25, when the part visible (with the Great Spot central) was dusky and evenly filled in, and the belt in every respect was one solid, unbroken shade. I have never seen it, before or since, so absolutely uniform in tint. A few days after this (September 28) faint forms began to appear in the equatorial regions near the Red Spot. The south band was usually well-defined at both edges, and rather narrow, the inner edge being more or less undulating. At other times, there were large, soft, dusky, feathery projections from it, spreading out to the equator; in almost every case, these streamed backward, towards the east limb, as if the south belt were moving faster than the equatorial region. The north band was markedly different from this. It was always much diffused towards the equator. The edges were sometimes festooned with dusky, cloud-like forms. I would refer to the drawings of Pl. III (November 10, 22); Pl. II (October 7, 10, etc.), as showing the differences in the two belts. A long light rift was frequently visible near the extreme north edge of the north band. From the fact that this always bore the same relative position to the bright spot in the south band, I infer that the north component of the equatorial band rotated in the same time as the south component; but from the retarded appearance of the dusky masses projected from the inner edge of the south band, and frequently from the north band, one might also infer a somewhat slower rotation at the equator. This, however, is a mere conjecture, with no other warrant than appearances.

In reference to this retardation of the masses projected from the south band toward the equator, I quote an observation of mine on April 1, 1886, respecting one of the most remarkable appearances that I have seen on *Jupiter:* "At $12^h 45^m$, three of the dark projections ranged along the inner edge of the belt and just south of the equator. I noticed that from the summit of each there extended for a short distance in a following direction, a dusky streak, looking like smoke. I was strongly impressed with the resemblance to what might be called a silhouette view of three volcanic peaks, ranged in a line and vomiting smoke, which a strong wind was carrying eastward!" (*Sid. Mess.*, May, 1886, p. 156.)

The History of the Formation of a New Belt.

In all the drawings previous to the 1st of November, 1880, a very thin line or belt is shown, just north of the north equatorial belt. In the first observation, in 1879, this narrow line was reddish, and formed a neat border to the north side of a delicate band or space that lay between it and the equatorial band. It was also the south edge or border to a delicate broad white band that encircled the northern hemisphere. Finally, the delicate band south of it faded, and became of the same tint as the light band to the north, thus leaving the border occupying the position of a distinct linear belt around the planet. This is what I have called the first north linear belt, or, simply, the first linear belt. It continued thus perfectly linear, without a mark on it, until the latter part of October, when it rapidly underwent a change so remarkable that I have thought it worth describing in detail. On the night of October 21, 1880, at $9^h 30^m$, this belt appeared a little swollen, or thicker than usual. On the 23d, the entire planet seemed to be undergoing a great change, so much so that I wrote in my note book: "*Jupiter* is undergoing some remarkable changes now; there are a great many degrees of shade, somewhat like ill-defined spots and light spaces, appearing in the southern hemisphere near the Great Spot. The space between the north edge of the north equatorial band and the first linear belt is deepening in tint, as it was last year—a grayish green. At 8^h the first linear belt near the following limb is knobbed in appearance, as if several little dark beads were strung on it, and at 9^h it was seen to have two pretty distinct, dusky spots on it, close to each other."

On account of the remarkable character of these changes I feel that it is proper, strictly as a matter of record, to give my notes in full:

1880. Nov. 1. *Jupiter* has been undergoing some remarkable changes. From the time the Red Spot began to appear until after its transit, the first linear belt was composed of a string of large dusky spots. I counted five, each as large as the shadow of a satellite. Under the best definition, they appeared as black as the shadows of the two satellites (I and II, shown in the drawing), and the belt elsewhere appeared thicker than usual.

Nov. 2. At $6^h 30^m$ the affected belt observed last night appeared very heavily marked.

Nov. 3. $7^h 45^m$. The disturbed portion of the belt just appearing. At $8^h 25^m$, the affected part reaches from the following limb to near

midway the disc. It is heavy, broad and uneven. $8^h 40^m$. The first portion of this is in transit; a number of roundish, cloudy masses on it clear to the following limb.

Nov. 4. It is heavily marked, and its following portion transited at $6^h 9^m$.

Nov. 7. 8^h. The belt faint and undecided; no trace of the affected part.

Nov. 8. Near 7^h. The belt now is heavily marked all the way across the disc, and dark, with remarkably large, distinct, knotty lumps, in places quite broad with them. The disturbed region plainly visible; almost the most conspicuous part of the planet. Near 9^h, that portion of the belt visible is not affected at all, but was faint and ill-defined.

Nov. 10. From $7^h 30^m$ until 11^h, the belt was very heavy and dark. It consisted of a strip of "veiling," pretty even at its northern edge, but undulating southwards; it was heavily nucleated at several points by heavy, blackish spots, and at these points the "veiling" was pressed outwards towards the equator. Later, that portion opposite the Red Spot, which was so heavily affected on November 1, was seen to be slightly wavy, but faint and ill-defined.

Nov. 11. Before the Red Spot had appeared the belt was affected as before. That portion opposite the Red Spot at transit was diffused and slightly wavy. Near 10^h, after the spot had disappeared, the belt was a pale blue, broader than usual.

Nov. 18. 7^h to 8^h. Opposite the Red Spot, the belt was very diffused and broad, and appeared slightly wavy where the spots of November 1 appeared.

Nov. 20. $9^h 49^m$. The belt is very diffused and faint, with no spots on it.

Nov. 23. $8^h 35^m$. Three large and intensely *black spots* nearing transit. The spots are as black as the shadows of the satellites.

Dec. 1. 7^h. The belt is broad, heavy and distinct across the entire disc. It is dotted with black spots. $7^h 20^m$. It is now heavier to the preceding side of the disc, and is faded and diffused following. $8^h 45^m$. The belt is now faint and diffused across the entire disc.

Dec. 2. $6^h 51^m$. It is faint and diffused, and no dark spots on it. At $7^h 37^m$, it is heavy with separate "blocks" or oblong spots. These are probably the ones seen on November 1, which have gone completely around the planet, and have now arrived at the point where they where first seen. They are about as conspicuous as

the equatorial belts, and are moving around the planet with great velocity.

Dec. 5. The large spots have drifted past the Red Spot, and appear as at last observation—broken—forming a disjointed belt. At 8^h, the belt is composed of a number of dusky spots that stretch from limb to limb.

Dec. 7. $7^h 19^m$. The belt is heavy and broken.

Dec. 9. 8^h to 10^h. The belt is heavy and uneven. The south edge has a light rim or border.

Dec. 10. The northern hemisphere is delicately beautiful. The south side of the new belt consists of beautiful curves, their inner (south) edge bordered with a light line. I notice that the equatorial edge of the north equatorial band has the same or corresponding curves to those in the new belt.

Dec. 14. $6^h 35^m$. The new belt consists of several large dusky spots.

Dec. 29. $7^h 40^m$. The new belt faint, the scolloped edge seen with difficulty.

Dec. 30. About 9^h, it is heavy and undulating.

Dec. 31. 8^h. The new belt is faint.

1881. Jan. 7. 8^h to 9^h. The new belt is deeply scolloped—long and regular sweeps; it fades northwards. There is no white rim to the scollops. The belt diffuses north as a grayish shade all over the northern hemisphere. The second and third linear belts that crossed the northern hemisphere in 1880 cannot be seen.

March 6. $7^h 30^m$. The new belt is much scolloped.

July 2. 15^h. There is a heavy diffused belt north of the equatorial belts, where, in 1880, existed the first linear belt. This is the final result of the spots that broke out on it November 1, 1880.

July 9. $14^h 30^m$. The new belt is broad and diffused, and of a brick-dust red.

Oct. 3. The new belt is very diffused. There is a dark line running through it a little north of the middle of the belt. [Is this the first linear belt?] A small, white spot, like a satellite, on its south edge, transited at $10^h 15^m$.

Oct. 14. 10^h. The new, diffused, reddish belt is double.

This is the complete history of the formation of at least *one* of the belts of *Jupiter*; and probably no more remarkable outburst has been witnessed.

During the time these striking changes were taking place the

weather was very bad, and only occasional glimpses of the planet could be had. These glimpses, though, gave sufficient evidence of the rapid changes that were taking place. These changes were so rapid and peculiar, and the weather so unpropitious, that no transits that could be positively identified as belonging to the same portion of the affected belt could be obtained, and therefore the motions of these spots could only be estimated. But it was clearly evident that they were extremely rapid. If the sketches refer to identical objects, the period, with reference to the Red Spot, would not be far from thirty days, or two-thirds of the period of the White Spot, with reference to the Great Spot.

Let us briefly review what the notes tell us about this disturbance. For, at least, over one year, a thin, uniformly even stripe around *Jupiter* existed north of his equatorial belt. About the last of October, 1880, both hemispheres of the planet were greatly affected by a disturbance that finally culminated in a great outbreak on this thin stripe, just mentioned. First, it became swollen in places; then, lumpy spaces appeared on it; next, small black spots were formed, each with a penumbra—not unlike a sun-spot: these had a very rapid motion westward on the planet, and enlarged and increased in longitudinal extent, becoming large, oblong, dusky spots, without a black nucleus. They then diffused into a "veiling," with condensations in it. This "veiling" became beautifully scolloped, its southern side consisting of graceful, light-rimmed curves, which decreased in sweep as they extended eastwards. Finally, these encircled the planet completely, diffusing northwards quite to the pole. The energies that produced the disturbance finally died out, and the beautiful curve-bordered belt lost its characteristic features and toned down to a broad, diffused, red belt, surrounding the planet; and this finally became double, and was apparently a fixed feature of the surface when I ceased to observe it.

The Polar Caps.

The north polar cap was variable in its color and in the distance to which it extended. It was frequently noted to be of a delicate wine tint; at other times it was pale gray. Its usual limit was the third linear belt, though on several occasions it extended nearer the equator. At these times the third belt was seen crossing it.

The edges of the south cap were seldom well-defined. I have never seen it of a warm tint. These caps have never been very deeply marked. One striking fact was noted on several occasions.

When dawn had whitened the sky the poles appeared to grow darker and more dusky in color. There was usually a marked difference in the appearance of the northern and southern hemispheres of the planet. The northern was free of spots, except several tiny *black* ones, which were visible for a long time on the third linear belt, and which did not have a greatly different period from that of the Red Spot. Graceful, narrow linear belts crossed this hemisphere, and light bands were often seen. In the southern hemisphere there was no such symmetry. The Great Red Spot, dusky shadings, strips or fragments of belts, were the characteristic features of the southern hemisphere.

It is a very difficult question as to which portion of the surface of the planet is the highest—whether the belts are at a lower depth than the whiter surface or otherwise. During these observations I was frequently impressed with the idea that the general matter of the equatorial belts was at a lower altitude. I was particularly struck with this on several occasions. A peculiar brushing-out or smearing of the bright surface adjacent to the south band, which was recorded on several dates, had every appearance of a blending of the light surface over and above the belt. Several times in 1886 a luminous spot was seen close to the northern edge of the north equatorial band that seemed to push the white surface over and above the belt. The more rapid rotation of the belt is also consistent with its being at a lower altitude.

At a number of occultations of the satellites I watched carefully for any evidences of their being seen through the edges of the planet, but saw nothing of the kind. Professor HOLDEN informs me, however, that, with the thirty-six-inch equatorial, the whole disc of a satellite has been visible within the planet's atmosphere, at every occultation he has observed. (See, also, the observations of 47 *Libræ* by *Jupiter*, as observed by Professor HOLDEN and myself, June 9, 1888. *A. J.*, vol. 8, p. 64.)

I would call special attention to the second drawing of 1880, November 1 (Plate II). There is a large lithograph of *Jupiter* published by the SCRIBNERS, from a drawing by TROUVELOT. This was made in Cambridge, Mass., November 1, 1880, (9^h 30^m, Cambridge mean time). The difference of longitude between Nashville and Cambridge is 1^h 3^m. My drawing was made at 8^h 30^m, Nashville mean time, adding the difference of longitude, and we have 9^h 33^m, Cambridge mean time, for my drawing, or within three minutes of the time of the drawing by TROUVELOT. That is to say, that while my

pencil, in Nashville, was marking on the paper, TROUVELOT, at Cambridge, Mass., was, at that identical instant, drawing the same thing. The two drawings are exactly similar in the main features. His telescope was larger than mine, and he, therefore, saw more details. To the left below the belt, on this drawing, are the first and second satellites; the first nearer the belt. On the Red Spot is the shadow of the second satellite, while near the equatorial belt is the shadow of the first moon.

I have collected nearly all the observations of transits of spots over the central meridian of *Jupiter's* disc, and present them in the following table. I would state, in reference to these observations, that the first ones to the latter part of September may be affected by an error in the times of as much as two or three minutes outside of the error of observation. I had no means of determining my time, and depended upon the tower clock of the University, which, I afterwards found, had not been carefully looked after during the vacation season. I therefore give them with the above caution. I regret this; for I believe the observations themselves were made with much accuracy for simple eye-estimates. Some that were obviously far out, from the above cause, I have rejected altogether.

In conclusion, I would express my indebtedness to Professor HOLDEN, without whose interest and encouragement these observations and drawings would never have been published.

DESCRIPTIONS OF THE DRAWINGS.

Plate I.

1879. Oct. 3. Shows the Red Spot and the area of light surrounding it, and the peculiar diffusion of the south band towards the south, which forms a bay around the following end of the spot. North of the equatorial bands is shown the narrow linear belt, which later on plays an important part in the drawings. This we have designated the first linear belt north.

1880. July 24. A very small dusky spot is seen between the equatorial belts and the south pole. The Red Spot is appearing at the following limb.

July 30. The peculiar mass of shading, referred to in the notes, is seen attached to the south preceding portion of the Red Spot.

Aug. 13. This shows the famous White Spot in the south part of the equatorial bands, near the following limb.

Aug. 16. The White Spot is nearer the Red Spot.

Aug. 17. Shows a group of small spots, and the mass of shad-

ing, and the Red Spot just coming into view around the following limb. The left-hand one of the three small spots is the same as that shown in the drawings of July 24 and August 1.

Sept. 10. The White Spot is shown in one of its brightest phases, with a luminous train following it near the equator. It has passed the Red Spot and left it far behind.

Sept. 16. Shows the shading now separated from the Red Spot, which it is leaving slowly behind.

Plate II.

1880. Sept. 18. This shows the thin red line springing from the south side of the equatorial belt and streaming backwards parallel to the equator, near the following end of the Red Spot. Two very small, very black spots are seen. One of these was visible for a great length of time on the second linear belt north. Though the Red Spot is shown in this drawing, the white one is invisible, being indeed on the other side of the planet at this time.

Sept. 24. The Red Spot is disappearing at the preceding limb, while the White Spot, with its train of light, is near the middle of the disc.

Sept. 28. The Red Spot is just past the middle of the disc, and the White Spot is fully within the following limb.

Sept. 30. (I) Satellite I is seen on the Red Spot, while its shadow is on the edge of the spot. The shading and two of the small spots in the southern hemisphere are also seen. (II) Satellite I and its shadow have now left the Red Spot. On this occasion I transited most of the disc as a dusky brown spot, south following its shadow. The White Spot is appearing at the following limb.

Oct. 7. Satellites I and II are in transit, partially hiding their shadows, which are close north following them.

Oct. 23. (I) The Red Spot is disappearing, and some dusky lumps are coming into view on the first linear belt north. These are the first indication of the great outbreak on that belt. (II) These swollen places in the belt are shown in transit.

Nov. 1. (I) The Red Spot is appearing, while the shadow of I is just skirting its north preceding end, and the shadow of II is on the spot. Near the middle of the disc, south of the equator, satellite I itself is shown as a dusky spot near transit, while satellite II is lost in the brightness of the disc. Near the north following limb a string of dark spots is coming into view on the first linear belt. (II) Both satellites now appear as small pale discs, relieved by the slight

duskiness of the planet near the preceding limb. The shadows have changed their places with respect to the Red Spot. The row of dark spots on the first linear belt is now in transit. These look like sun-spots—a black umbra surrounded by a penumbra. These are, doubtless, the same spots that are shown in an incipient stage of development in the sketches of October 23. They are, therefore, in rapid motion around the planet. (Compare their relative position to the Red Spot in the first drawing of October 23 with that of the second drawing of November 1.)

Nov. 7. We have the White Spot in this drawing on the opposite side of the planet to the Red Spot. Two other bright spots are just ahead of it.

Plate III.

1880. Nov. 8. The second satellite is seen as a white spot on the south following end of the Red Spot, while I is partially on the north preceding end as a dusky spot, and its shadow is shown to the right of the center below the equatorial belt. That portion of the first linear belt north now visible with the Red Spot has not as yet been affected by the eruptive spots.

Nov. 10. (I) The shadow of III is seen at a high southern latitude, and a mass of dusky shading is north following it. Another phase of the new spots on the first linear belt is shown. (II) The Red Spot is now visible, and the affected part of the belt has been carried off the disc by rotation. That portion now seen is faint and wavy.

Nov. 18. The White Spot is in one of its brilliant phases, just above the following end of the Red Spot.

Nov. 20. The White Spot has now moved to a point near the preceding end of the Red Spot, and is in one of its quieter phases.

Nov. 22. (I) Another phase of the northern spots is shown. The two small spots in the southern hemisphere have been shown in previous sketches. The Red Spot is not in sight. (II) The Red Spot and the White Spot are both visible—the White Spot having left the Red Spot far behind.

Nov. 23. (I) The distance between the White and Red Spots has sensibly increased since the drawing of last night. (II) The Red Spot is disappearing, and the first portion of the affected belt is coming into view at the north following limb.

Dec. 2. (I), (II), (III) show further phases of the disturbance.

Plate IV.

1880. Dec. 9. Shows the spots becoming connected by long loops bordered with a brilliant line on the equatorial side.

Dec. 10. (I) Another portion of the new belt visible when the Great Spot is leaving the disc—the shadow of a satellite on it. (II) This drawing was made after the Red Spot had disappeared.

1881. Aug. 29. In the place of the first linear belt north there is now a broad diffused reddish belt that completely encircles the planet. The remarkable spots and the beautiful light-rimmed curves have disappeared, and all the other singular transformations that the first linear belt north underwent have finally ended in the formation of this now persistent diffused red belt.

Nov. 5. The Red and the White Spots are again near each other. The diffused red belt, the scene of the great disturbance of 1880, remains unchanged. Two of the small black spots previously seen are shown on the second linear belt north—which, suffering almost total obliteration during the changes of 1880, is now as marked as ever.

1885. May 12. The Great Spot is now very faint. The south equatorial band diffuses southwards around the following end of the Red Spot, as in 1879.

1886. April 22. A white cloud has formed over the middle of the great Red Spot, almost obliterating it. The peculiar bay formed around the following end of the spot by the south band is now very persistent.

I have observed a few abnormal transits of Satellites I, III and IV, which are given here, so that they may be available for a study of the causes of these dark and black transits.

Satellite I.

1880. Sept. 30, occasionally seen during transit as a brownish spot; Nov. 1, seen in mid-transit as a dusky spot; Nov. 8, seen in mid-transit as a dusky, brownish spot; Dec. 1, seen in mid-transit quite plainly as a dark spot—quite dark.

Satellite III.

1879. Aug. 2, very black nearly all the way across—mistaken for shadow; Sept. 14, black during transit.

1880. Sept. 28, carefully watched throughout transit, not visible except near limbs—not a black transit; Dec. 30, at 8^h 30^m, seen in a high south latitude as a small, black spot; continued visible as

black spot until near *p.* limb, and only lost its blackness at $9^h\ 4^m$. Ten minutes after emergence it was certainly as bright as that part of disc on which it appeared as black as a shadow.

1880. Nov. 10, the shadow of III appeared fuzzy and not black. It seemed to be affected by penumbra.

1881. Oct. 13, at inferior conjunction it passed the south pole with only three-quarters of its disc on the planet—carefully estimated.

1883. Feb. 12 ($9^h\ 40^m$), small, black.

1885. May 9 ($7^h\ 15^m$), on north edge of belt very black, and remained dark until close to limb.

Satellite IV.

1885. Feb. 27, at $6^h\ 15^m$, it is as black as its shadow, and about half as large—it remained dark up to nearly the moment of emergence.

1886. May 8 ($9^h\ 20^m$), IV near north pole, very black.

Observed Transits of Spots on *Jupiter*.

(NASHVILLE MEAN TIME.)

Date.	Red Spot.			White Spot.	*a*	*b*	*c*	*d*
	P. End.	*Middle.*	*F. End.*					
1880.	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*
July 10.	14 40	15 22	15 47	....	....	....	....	....
" 17.	15 20	15 44	16 04	....	....	....	....	....
" 24.	16 12	16 40	16 57	....	....	....	....	....
" 29.	15 17	15 43	16 11	....	14 00	....	....	....
Aug. 1.	16 52	17 18	17 42	....	15 18	....	....	....
" 7.	....	....	....	....	16 09	....	....	....
" 11.	....	11 32	12 01	....	....	....	....	....
" 13.	12 36	13 04.5	13 32	....	....	....	....	....
" 16.	10 16.5	10 35	10 56	....	....	10 36	....	....
" 17.	15 55	16 19	16 41	....	14 14	....	....	....
" 23.	10 54.5	11 19	11 40.5	....	....	....	....	....
" 28.	....	10 24.5	10 48.5	....	....	....	....	....
" 30.	11 34.7	11 58.2	12 24.2	....	....	....	....	....
Sept. 9.	9 51.7	10 15.2	10 39.2	....	....	....	....	....
" 14.	....	9 27±	....	....	....	10 21	....	....
" 15.	....	....	....	....	....	9 47	....	....
" 16.	10 32	11 02	11 24	....	....	....	....	....
" 18.	12 14	12 37.7	13 03	....	....	12 22	....	....
" 25.	12 58	13 24	13 45	....	10 46	....	....	....
" 28	10 28	10 53	11 17	....	....	10 38	11 40	....
" 30.	12 01.5	12 29.5	12 54	....	9 48	12 11	....	....
Oct. 1.	7 57	8 25	8 52	....	....	....	....	7 28
" 6.	7 01.5	7 29.5	7 57.5	....	....	....	8 18	....
" 7.	12 45	13 13	13 40	....	10 24	....	....	....
" 10.	10 13.5	10 39.5	11 08.5	....	....	10 26.5	....	....
" 13.	7 44	8 10	8 36	....	....	....	....	....
" 20.	8 29	8 53	9 17	....	....	....	....	....
" 22.	....	10 30	....	....	....	....	....	....

DATE.	RED SPOT.			WHITE SPOT.	*a*	*b*	*c*	*d*
	P. End.	*Middle.*	*F. End.*					
1880.	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*
Nov. 1.	8 19	8 48	9 10.5	....	....	....	....	....
" 4.	....	6 15	6 39	....	....	....	....	....
" 7.	....	....	....	7 59	....	....	....	....
" 8.	9 06	9 31	9 57	....	....	....	....	....
" 10.	10 44	11 09	11 33	....	....	....	....	....
" 11.	6 34	6 57	7 25	....	....	....	....	....
" 18.	7 17	7 42	8 09	....	....	....	....	....
" 20.	8 58	9 22	9 48	....	....	....	....	....
" 22.	10 40	11 01	11 29	10 18	7 46	....	....	9 07
" 23.	6 32	6 53	7 20	....	....	....	....	....
Dec. 2.	8 56	9 15	9 41	6 27	....	....	7 33	7 23
" 5.	6 28	6 46	7 11	....	....	....	....	....
" 6.	....	....	....	8 53±	....	....	....	....
" 7.	7 59	8 23	....	....	....	....	....	....
" 9.	9 37	10 01	10 24	....	....	....	....	....
" 14.	8 46	9 09	9 34	9 20	....	....	....	7 05
" 29.	....	....	....	7 41	....	....	....	....
" 31.	7 45	8 08.5	8 33	....	....	....	....	....
1881.								
Jan. 7.	8 39	9 01	9 24	8 02.5	....	....	....	....
Mar. 6.	6 52	7 14	7 36	....	....	....	....	....
July 2.	....	....	15 21	....	....	....	....	....
" 9.	15 12	15 34	15 57	....	....	....	....	....
" 11.	16 47	....	....	....	....	....	....	....
" 21.	15 04.5	15 27	15 50	....	....	....	....	....
" 28.	15 53	16 12	16 36	....	....	....	....	....
Aug. 3.	....	....	....	14 42.5	....	....	....	....
" 5.	...	....	....	15 46	16 06	....	....	....
" 29.	....	....	....	....	15 39.5	....	....	....
Oct. 10.	....	....	17 32	....	....	....	....	...
" 29.	....	....	....	10 25	....	10 15±	....	....
Nov. 3.	....	6 50±	....	8 24	....	....	....	....
" 5.	8 09	8 30	8 54	9 34	....	9 20	....	....
" 12.	9 52	9 14	9 42	8 44	....	....	....	....
" 15.	....	6 45	7 08	....	....	....	....	....
" 26.	....	....	....	7 27	....	....	....	....
" 29.	8 54	8 15	8 37	....	8 30±	....	....	....
1882.								
Jan. 23.	8 19	8 40	9 03	....	....	....	....	....
Feb. 4.	8 08	8 28	8 49	9 07	....	....	....	....
April 27.	....	....	6 50±	....	....	....	....	....
1885.								
April 25.	....	10 41.5	....	7 56.5	....	....	....	....
May 12.	....	9 43	....	....	....	....	....	....
May 13.	....	....	....	8 48	....	....	....	....
1886.								
April 22.	....	10 18.6	....	....	....	....	....	....
1888.								
*July 24.	11 51.9	12 08.4	12 29.8	....	....	....	....	....
1889.								
*May 31.	....	....	15 09.3	....	....	....	....	....
*June 9.	....	....	17 48.4	....	....	....	....	....
" 17.	....	13 53.0	....	....	....	....	....	....
*July 2.	....	11 19.1	....	....	....	....	....	....

* With twelve-inch at Lick Observatory. Like the others, in Nashville mean time.

The transits of a few objects were observed with the six-inch, at the Vanderbilt University Observatory, as follows:

DATE.	*e*	*f*	*g*
	h. m.	h. m.	h. m.
1885. April 21	8 02.5	.....	.....
" " 22	.....	7 05.5	6 55.7
" " 25	7 08.2	.....	.....
" " 29	.....	7 54.5	7 46.5
" May 9	8 42.5	.....	.....

NOTE (explanatory of the table of transits).—*a* is the small spot mentioned as having been seen 1880, July 24, and subsequently; *b* is a small black spot, the *p*. of two shown on the second linear belt north in the drawing of 1880, September 28, and subsequently; *c* is the second of these two black spots; *d* is the shading spoken of in connection with the Red Spot; *e* is a luminous spot, sometimes recorded as a notch in the north edge of the north equatorial band, probably not all the same object; *f* is a very small, intensely black spot *on* the south part of the equatorial belt—round, and like a satellite's shadow, but smaller; *g* is a luminous spot or notch in the north edge of north equatorial band.

DRAWINGS OF *JUPITER* MADE WITH THE 26-INCH EQUATORIAL, AT WASHINGTON, DURING 1875.

By Edward S. Holden.

During June and July, 1875, I made drawings of *Mars* and *Jupiter*, in colored crayons, for the purpose of comparing the tints on these two planets. The drawings were all made with the twenty-six-inch equatorial of the United States Naval Observatory, usually with a magnifying power of 400, and no pains were spared to make correct delineations, both as to forms and colors. From one cause and another, these drawings have not been published.

I beg to present a photograph of the sketches of *Jupiter* to the Society.

The original colored drawings [exhibited to the meeting] will be deposited in the library of the Lick Observatory, where they will always be available for comparison with more recent work. Below, I give the few notes which should accompany the drawings, which are reproduced in Plate V. It will be interesting to compare these

drawings with the admirable series by Mr. BARNARD, which are given in Plates I to IV.

There are three general remarks to be made on these drawings. In the first place, while the general features of the planet's surface have remained about the same from 1875 to 1889, there has been an entire change as to the form and disposition of the details. In the second place, the disposition of color on the surface of the planet has entirely changed, also. In 1889 there is very little of the red color to be seen, except in the great central belt, while in 1875 red belts were seen almost to the poles. Thirdly, the characteristic red color itself has changed in a surprising manner since 1875.

The color of the red markings in 1875 was most carefully matched in crayons, and I was finally satisfied with the tint of the drawings. In 1881 I found that the same crayons (pieces of which I had preserved) would no longer match the red belts. In 1889 the color of the red belts is entirely different from that previously drawn. All the observations were made with CLARK objectives (of 26, 15½ and 36 inches aperture), which had their color-corrections very much alike. Unfortunately, it is not practicable to reproduce these colors in Plate V. The notes follow:

The top of the drawing is south; the right-hand side is east, or following.

1875. June 16, seeing not good; June 18, hazy; June 24, the columnar structure in the southernmost belt is somewhat too coarse; July 13, the position of the shadow of the satellite is for $8^h\ 40^m$; July 16, planet unsteady.

NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

ON THE DETERMINATION OF THE BRIGHTNESS OF STARS BY MEANS OF PHOTOGRAPHY.

Dr. CHARLIER, assistant in the Observatory at Stockholm, has prepared a memoir* on the use of photography in determinations of the brightness of stars, which has been published by the Astronom-

* *Ueber die Anwendung der Sternphotographie zu Helligkeitsmessungen der Sterne*, von C. V. L. CHARLIER. *Publication der Astronomischen Gesellschaft*, XIX. Leipzig 1889, 4to. (pp. viii, 31).

ical Society of Germany, and dedicated to the Pulkowa Observatory, on the occasion of the fiftieth anniversary of its foundation, August 19, 1889.

The subject treated is so new and so important that it will not be out of place to give a brief review of Dr. CHARLIER's excellent treatise here, and to add some general considerations on the same question. The importance of this subject will be obvious, when we consider that within the next decade we may expect to have at least two sets of photographic maps, covering the whole sky from pole to pole, and including millions of stars down to the fourteenth magnitude.

Besides these systematic maps, hundreds of charts of special regions will be made. Each star on each of these maps will have impressed its image on a negative plate as a disc of measurable size. Hence the magnitude of each and every star *can* be determined if necessary, and when the catalogue of the stars to the eleventh magnitude, also proposed by the Congress, is constructed, the magnitude of each one of these two million stars *must* be given.

There are two imperative questions to be settled before the principles on which this great work is to be done can be considered to be established. The first and more special question is, What is the relation between the diameter of the photographic image of a star (d) the aperture and focus of the telescope employed (a, f) and the exposure time (t), and what is the relation between the (photographic) brightness of a star and the diameter of its image? Having satisfactorily determined the relations just named, the second and more general question presents itself, namely: On what fundamental principles ought the photographic magnitudes of the stars to be assigned?

These two questions are not treated separately in the work before us. Its second paragraph states the problem of the photographic photometry of stars as follows: It is "to determine the function which gives the relation between the size of the photographic image and the photographic brightness of the star, and to determine the constant quantities in this function *in such a manner that the resulting photographic brilliancies shall correspond accurately throughout with the brilliancies determined visually.*"

In my judgment, this is by no means the problem of stellar photographic photometry. It is impossible, in general, to fulfill that portion of the above statement which I have printed in italics. The difference between the photographic and the photometric magnitudes of *Aldebaran*, for example, is more than one and one-half

magnitudes, and so with other stars. We may leave this part of the question for the moment, and proceed to give a brief analysis of Dr. CHARLIER's memoir, laying stress principally on the novel portions of his work.

The observations which he discusses were made with a photographic lens by STEINHEIL of 3.19 inches aperture and 39.37 inches focus ($\frac{f}{a} = 13$). The plates took in an area of twenty square degrees. The images were satisfactory over a field of about three degrees in diameter. Stars to eighth magnitude, inclusive, left trails. The plates employed were made in Lyons, by LUMIÈRE. Four plates are discussed. All were exposed on the *Pleiades*, as follows: No. 2, $t = 13^m$; No. 4, $t = 2^h$; No. 24, $t = 1^h30^m$; No. 26, $t = 3^h$. The plates were exposed at very different altitudes, and no account is taken of absorption of light by the atmosphere.

Dr. CHARLIER finds two defects in the plates: first, bright rings round the larger stars, which he proves to be due to reflections from the back of the plate (the well-known halation images); and, again, false stars. He finds no less than fifty-six such false stars on his plate No. 26. They were probably due to defects in the manufacture of the plate itself.

As subjects for experiments he chose the *Pleiades*, because their photometric magnitudes are accurately determined, and also because they afford a variety of magnitudes within a comparatively small area.

Although he does not expressly mention the fact, the *Pleiades* have the special advantage for his purpose of being all of the same spectral type. A region containing many very red or many very blue stars would have given a corresponding number of anomalous results, which are avoided by choosing a group of stars of one type. The diameter of each star on each of the four plates was measured. Calling H the brightness of a star, and m its magnitude, and 0.4 the light ratio, Dr. CHARLIER starts with the formula

$$(1) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad H = (0.4)^m$$

That is, he assumes that the brightness of a first magnitude star ($m = 1$) is 0.4. It is better to write this formula, I think,

$$(2) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad H_m = (0.4)^{m-1}$$

which for $m = 1$ gives $H_1 = 1$. Assuming the equation (1), however, and further assuming that when d is zero, H must be zero, he finds

$$(3) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad m = a - b \log d$$

Here it may be remarked that, in fact, H is not necessarily zero for $d = o$, because all stars below a certain brightness will fail to produce an image on the plate, no matter how long the exposure may be—for any practical exposure-time. The brightness of a star must be above a certain finite limit in order to produce any impression at all. The assumption is sufficiently accurate, however, for the purpose in hand. The relation between exposure-time and diameter of star image is next determined from a series of exposures on *Polaris*, assuming the form

$$(4) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad d = d_0 \, . \, t^k$$

That is, that the diameter of the star-image varies as the k^{th} power of the time. From *Polaris* (two plates) the values of k are 0.243 and 0.249; from a star 5th mag. k results 0.243,—hence, the numerical value of the diameter of the star-image varies as the fourth root of the time or

$$(5) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad d = d_0 \, . \sqrt[4]{t}$$

This formula shows that the diameter d will be doubled when the exposure t is increased sixteen-fold.

If there are no limits to the formula it also shows that, for the telescope and plates employed, an exposure of $\frac{1}{16}$ second would give a perceptible image. Without considering the question of the *range of sensitiveness* of plates I may state it as my opinion that the formulæ of Dr. CHARLIER and those of Professor SCHAEBERLE (*Publ. Ast. Soc. Pacific*, No. 4) can (at present) be applied safely only to *over-exposed* stars, and that there is a superior limit also beyond which they are no longer applicable. Both Dr. CHARLIER and Professor SCHAEBERLE have found that the stars with the longest exposure are best fitted for the determination of magnitude.

We may now quote, without further remark, the final formula to which Dr. CHARLIER is led, which gives the relation between m (star's magnitude), d (diameter of star-image on plate), and t (exposure time). It is

$$(6) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad m = A + B \log d + C \log t$$

In the particular plates in question the constants A, B and C are

$$A = +\ 17.2 \qquad B = -\ 6.75 \qquad C = +\ 1.69$$

A, B and C are proved to be constant on the four plates in question; t is expressed in minutes.

From the formula (6) the photographic magnitudes of fifty-two of

the brighter stars in the *Pleiades* were computed, and compared with the photometric magnitudes of the same stars as determined by Dr. LINDEMANN, at Pulkowa. (Table III.)

The mean difference between the photographic and photometric magnitudes is ± 0.22 mag. The differences occur 0.6 mag. (twice), 0.5 (twice), 0.4 (4 times), 0.3 (12 times), 0.2 (12 times), 0.1 (10 times), 0.0 (7 times). Two stars are either variable or red. The individual results for the photographic magnitudes from the four plates agree well. The mean difference is 0.10 mag. The largest difference is 0.4 (occuring twice).

Dr. CHARLIER makes the important remark that the red stars, etc., which are thus discovered in the group of the *Pleiades*, are very suitable for a determination of its parallax, since they differ in spectral type, and are therefore *presumably* not members of the group. A few moments' examination with a small spectroscope will, however, be a surer indication in similar cases.

Section III of the memoir is devoted to a comparison of the results of the Stockholm photographs with those obtained by Professor PICKERING, at Harvard College, and by Dr. SCHEINER, at Potsdam. The linear formula deduced by the latter is shown to be inferior to the logarithmic form adopted by Dr. CHARLIER; and in Table IX it is shown that the systematic differences between the results at Harvard College and at Stockholm are likely to be due to constant errors in the H. C. O. results. In all this discussion, as has been said, the effect of atmospheric absorption is omitted, as it has been in all previous publications of the kind. It is of considerable amount, however.

Section IV of the memoir is chiefly concerned with a comparison between the photometric magnitudes given by WOLF, of Paris, for 571 of the *Pleiades* stars and the photographic magnitudes of the same stars derived from one plate (only) taken at Stockholm. Twenty-eight of WOLF's stars do not appear on this plate; *en revanche*, it contains more than 100 stars not in WOLF's catalogue. In passing, we may remark that the single Stockholm plate made in three hours has a value at least comparable with the chart of M. WOLF, which was the result of many months of labor. It is worth while to remark here that it is highly desirable for the present to make every result derived by photography depend on two negatives at the very least. A comparison of the scales of WOLF and CHARLIER closes this section and concludes the important work.

We may now say that the present memoir and that of Professor SCHAEBERLE, previously cited, have fixed the form under which discussions of this character must be made in future. For every telescope a relation between the diameter of a star image and the corresponding exposure must be deduced in the form $d = \Phi$ (log t).

The constants of this formula will vary with the aperture, focus, plate, site, and with the spectral type of the star, and will probably be applicable only within certain limits of absolute brightness and within certain limits of exposure time.

The memoir of M. CHARLIER is an excellent example of the method of discussion which must be adopted to determine this function for all cases where the prime object is to make the photographic magnitudes harmonize as nearly as possible with the photometric. The real fundamental question is, however, Should any endeavor be made to harmonize them? I proceed to discuss this point as briefly as possible, in the light of our present knowledge, since it is the most important question remaining open for settlement.

Establishment of the Present System of Visual Magnitudes.

Let us consider, very briefly, the history of the introduction of the present system of visual magnitudes. The main epochs in this history are very few. The first is that of PTOLEMY (A. D. 150,) who arbitrarily assumed the brightest stars to be of the *first*, the faintest which he could see, to be of the *sixth* magnitude. The other stars were divided into classes of 2d, 3d, 4th, 5th, etc., magnitudes. The second great event in this history is the publication of the *Uranometria Nova* by ARGELANDER, in 1843. He adopted the general rules laid down by PTOLEMY, and followed by SUFI, TYCHO and BAYER. The brightest stars were called first magnitude, the faintest visible to the naked eye were called sixth magnitude. Stars of the classes 2, 3, 4, 5, etc., were intermediate. By FECHNER'S law, it necessarily followed that equal differences of sensation corresponded to equal *ratios* of light; or that the light of a star of m^{th} magnitude must be $\frac{1}{\delta}$th part of the light of a star one magnitude brighter $(m-1)$. Measures of this *light-ratio* δ show its numerical value to be 0.4 very nearly, omitting all questions of small variations, etc.

The *Durchmusterungen* of ARGELANDER, KRUEGER, SCHOENFELD and THOME will determine the visual magnitude of every star in both hemispheres as bright as the tenth magnitude by this same scale. That is, if the brightness of a star of the first magnitude is unity, the brightness of a star of the m^{th} magnitude is

$$(7) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad H_m = (\delta)^{m-1} \text{ where } \delta = 0.4$$

The universal practice of modern observers has extended this scale from the tenth down to the sixteenth or seventeenth magnitude (the faintest stars now visible in the largest telescopes). Thus the *accidental* choice of the sixth magnitude as the limit of the naked-eye stars by PTOLEMY has fixed the light-ratio and the practice of all astronomers with regard to visual magnitudes for all time to come. It is to be noted that if PTOLEMY's work on visual magnitudes were to be done again *de novo*, and absolutely independently, the method chosen would be essentially the following: *One* standard star would be chosen (*Polaris*, in our hemisphere). This star would be compared with a selected group of stars, and the fact of the constancy (or the law of the variation) of its light during the course of the observations would be established. Every other star would be compared with *Polaris*, either directly or indirectly, and its relative light determined. Some convenient magnitude would be *arbitrarily* assigned to *Polaris*, and some convenient light-ratio would be *arbitrarily* assumed. The magnitude of any and every star would then be deduced from the measured ratio of its brightness to that of *Polaris* by a formula like our (7) in which the numerical value of δ would be assigned on grounds of convenience alone. It is very likely that the value $\delta = 0.4$ would be again chosen, because the tenth part of a magnitude (easily written with one place of decimals), thus defined, is about the limit of perception of the most highly trained human eye.

Such, I conceive, would be the process adopted if the whole question of visual magnitudes was entirely open, and if a Congress of Astronomers were called in 1890 to decide on the proper methods to be followed in fixing the visual magnitudes of the stars anew, or for the first time. The process is simple, it is complete, it is logical, it is sufficiently accurate for all conceivable uses to which visual magnitudes are to be put. The use of a visual magnitude assigned to a star is chiefly to determine its brightness at one epoch, so that observations at other epochs will determine whether there have or have not been changes in its light. It is from celestial bodies which are subject to change, and chiefly from these, that we can hope to learn anything of the nature of celestial bodies in general. A secondary convenience in having a magnitude assigned to a star is to aid in identifying, classifying and describing it.

Establishment of a System for Determining Photographic Magnitudes.

The International Congress of Astronomers will have to decide the question as to how to define the photographic magnitude of a star. They will soon be in possession of plates on which millions and millions of stars have impressed themselves. The diameter of each one of these stars can be measured. The photographic brightness of each one of these stars relative to the photographic brightness of *Polaris* (for example) can be readily determined. What *magnitude* shall be assigned to each one of these stars? Dr. CHARLIER'S answer to this question has already been given. He would assign to each one of a group of stars a photographic magnitude, deduced on the principle that the mean deviation of their photographic magnitudes from their visual magnitudes should be as small as possible. If the same star occurs in two or more different groups, it will certainly have different magnitudes assigned to it, according as one or the other set of standards is employed. The same method has been followed by Mr. ESPIN and by the Harvard College Observatory in all of its many important publications on this question, notwithstanding the fact that (owing to the color of a star) the photographic and visual magnitudes not infrequently differ by at least *two whole magnitudes*. That is, if the visual brightness be expressed by 1.00, the photographic brightness of the same star may be no more than 0.16, or only one-sixth part. Such anomalies must in the nature of things constantly appear for a considerable percentage of the stars. A tolerable agreement is possible for perhaps eighty per cent. of the larger stars, and even here there will be small persistent differences. For those remaining, the disagreement will be more or less marked, according as the spectral type of the star in question varies more or less from the average type. The reason of this is well known. The eye is sensitive to rays which fall between the FRAUNHOFER lines B and G (approximately) of the solar spectrum. The maximum brilliancy to the eye is somewhere near the line *b*. The photographic plate is sensitive to rays falling between F and N of the solar spectrum (approximately). The plates now in use are sensitive in the highest degree to rays of about the wave length of the line G.

Whenever we have a group of say five hundred stars, whose spectra are nearly all of the same type (as the *Pleiades*, for example,) we can measure for each star the relative energy of the light in the portion of its spectrum between B and G (by the eye), in that between F and N (by the photographic plate), and, *as the energy is distributed accord-*

ing to the same law in the spectrum of each star of the group, we can determine constants of reduction which *will* make the photographic magnitudes of the various stars agree well with their visual magnitudes. If, however, two hundred of the stars are very red, one hundred very blue and two hundred of the ordinary type, it is, in the nature of things, impossible to bring the photographic and the visual magnitudes to a good agreement. The very red stars will always appear brighter to the eye than they do on the plate, and the very blue stars will always appear fainter to the eye than on the plate, and there is no process of reduction which will smooth away a difference in their magnitudes which is inherent in their nature. If there were such a process, it would be most unwise to employ it. When I see that a star is of the visual magnitude 1 and the photographic magnitude 2.5, I at once learn something of the nature of this star's spectrum, and so in like cases.

It therefore seems to be a rational and a useful plan to leave out all consideration of the visual magnitudes of stars in determining their photographic magnitudes. A simple and most satisfactory method of procedure would be to assume *Polaris* as the standard star of the whole sky, and to fix its magnitude (when in the zenith of a station at sea level) at 2.00, once for all; to select a set of secondary standards, distributed round the equator, and to determine the brightness of each one of these stars in terms of that of *Polaris* (a proof of the constancy of the light of *Polaris* being thus attained). Important groups like the *Pleiades*, etc., would also have their brightness determined in terms of that of the standard. The brightness of the principal Southern stars should also be fixed in terms of *Polaris* indirectly through the *Pleiades*, etc. A light-ratio should be selected on grounds of convenience alone and the photographic magnitude of every star should be determined by an equation like our equation (7) in terms of a single standard star with a definite light ratio.

If this programme were to be followed, we should simply have to add to our star-catalogues another column headed "Photographic Magnitude," which would immediately follow the column "Visual Magnitude." The agreement or disagreement of the two numbers would tell us something of the nature of the spectrum of each star. In order to have the work exact, it would be necessary that all the stars should be photographed on one kind of plates, as is now done by the Harvard College Observatory, and as will be done by the International Photographic Congress. The photographic Southern

Durchmusterung might for convenience have its magnitudes expressed in visual units, though the DM of the Cordoba Observatory will make this unnecessary, and will, in fact, make it distinctly to the advantage of science if the photographic DM is made *entirely* photographic. The International map of two million stars to the eleventh magnitude should, in my judgment, give photographic magnitudes *alone*. I can conceive of no advantage to be gained by determining the approximate visual magnitude of these millions of stars at all comparable with the labor involved. In any event, it would seem that the photographic magnitudes should be given whether the visual magnitudes are or are not.

Such, it appears to me, are the general principles which should govern in the determination of star magnitudes by photography. I have set them forth because no amount of discussion at this stage can be called superfluous. After the International Congress has once settled its methods of procedure, it will be the duty of all co-operating observatories to conform to the spirit and to the letter of the methods finally adopted. As long as they are not yet adopted any suggestions, however simple, cannot fail to be of use.

The Lick Observatory is endeavoring to make a modest contribution to the general subject of which we have spoken. Professor SCHAEBERLE has made observations at Mount Hamilton (4209 feet above sea), and will make observations at Cayenne, South America, (nearly at sea-level), to determine the photographic atmospheric absorption at zenith distances between 0° and 70° or 75°. He has already compared the *Pleiades* and other stars with *Polaris*, and will compare the principal Southern stars with the *Pleiades*, etc. In this way, his observations, if successful, will enable us to transfer the standards of the Northern Hemisphere into the Southern.

The immense work now in progress in both hemispheres under the auspices of the Harvard College Observatory will afford material for a thorough discussion of the whole subject. The contributions of Dr. CHARLIER and Professor SCHAEBERLE have established the final form under which special discussions of this kind must be made. The only part of the subject remaining for settlement is that which relates to the establishment of the fundamental principles on which the final methods of reductions are to be based. I have endeavored, in what precedes, to set forth what seems to me to be a satisfactory system, at once simple and comprehensive. E. S. H.

VARIATIONS OF THE SURFACE OF MARS.

In the second volume (1888) of the *Bulletin de la Société Astronomique de France*, M. FLAMMARION has two long and studied articles on the *markings* of the planet *Mars*. He is careful to present a great number of *fac-simile* drawings of the planet, which date from 1659 to 1888, so that the evidence which he has used is before the eyes of the reader. After showing that drawings of *Mars* may differ greatly from each other on account of differences of eyes, methods, interpretation, instruments, atmospheric influences both on *Mars* and the earth, and on variations of the inclination of the planet's axis, he goes on to show that there still remain variations which are (probably) not due to any of these causes, and which therefore are to be attributed to real variations in the surface of the planet itself.

Most of the paper is devoted to an examination of the evidence of the drawings. (In this connection it is well to refer to a set of articles by Professor SCHIAPARELLI, in *Himmel und Erde* for Ocrober, November and December, 1888, where the same questions are treated also in a masterly manner.) At the close of this examination M. FLAMMARION feels authorized to draw the following conclusions as established facts—leaving all speculation to one side:

I. "There are permanent markings on the surface of *Mars*, which in all probability represent (*'doivent représenter'*) seas, lakes, regions of water of various kinds, etc. (It has long been known that on this planet there are polar snows which melt in summer, clouds, and the vapor of water shown by spectroscopic observations.)

II. "These markings are permanent; they are seen to-day in the same regions where they were observed in the seventeenth and eighteenth centuries. They are not atmospheric products, then, such as are shown, for example, on *Jupiter*.

III. "However, while they are permanent they are not invariable. They change both in extent and in depth of tone, in different years and without doubt during different seasons [seasons of *Mars*].

IV. "There are some regions which are specially variable. These appear to hold a middle place between continents and seas, and to be marshy lands, which are in turn elevated above and submerged below a thin layer of water.

V. "The continents of *Mars* appear to be flat; and subject to inundations in nearly all their extent.

VI. "The northern hemisphere is more elevated than the southern; the seas are chiefly in the southern hemisphere, and they do not appear to be deep.

VII. "The evaporation on *Mars* is, without doubt, rapid and considerable. Millions of cubic yards of water pass readily from the state of vapor to the state of liquid, and millions of acres pass from the continental to the maritime aspect.

VIII. "Water is perhaps not the only agent concerned in these changes. The general order of things is very different on *Mars* and on the earth."

This is not the place to examine the conclusions critically. In a general way, they all depend upon the assumption that the darker markings on *Mars* represent bodies of water. As this is quite probable (though by no means proved as yet) the eight theorems given above may serve as points of departure in the further working out of this plausible hypothesis. E. S. H.

Stability of the Great Equatorial.

Observations for the position of the great telescope have been made by Messrs. Schaeberle and Keeler, as below:

1888, July	27,	azimuth	$= + 36''$;	level =	8″ too low.
1889, May	18,	"	= ——	"	= 36″ " "
Sept.	16,	"	$= + 83''$	"	= 58″ " "

There appears to be a slight progressive change in level and probably in azimuth.

Mountain Observatories.

Telescopes . . . . "cannot be formed so as to take away that confusion of rays which arises from the tremors of the atmosphere. The only remedy is a most serene and quiet air, such as may perhaps be found on the tops of the highest mountains above the grosser clouds."—Sir Isaac Newton, in his *Opticks*, A.D. 1730.

Rainfall on Mount Hamilton.

Meteorological observations have been kept at Mount Hamilton since 1880. The following table of rainfall on the summit is the best available summary. This rainfall is considerably more than that in the Santa Clara Valley near San José (about 13.4 inches) and it is probably considerably less than the fall in some of the cañons and valleys immediately surrounding the mountain. The great variations in the annual amount of rainfall are interesting from a meteorological

point of view, and decidedly inconvenient from a practical one, especially as our reservoir capacity is not quite adequate. E. S. H.

Rainfall at Mount Hamilton in the Years 1880–89.

Month.	1880–81	1881–82	1882–83	1883–84	1884–85	1885–86	1886–87	1887–88	1888–89
	in.	in.	in.	in.	in.	in.	in.	in.	in.
July	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
August....	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.02
September.	0.00	0.10	0.00	0.65	0.65	0.15	0.00	0.33	0.49
October...	0.00	0.33	6.16	2.15	3.71	0.05	0.60	0.09	0.03
November*	0.50	0.91	3.45	1.48	0.01	——	2.82	0.90	3 27
December .	9.68	9.72	1.93	2.05	33.84	——	2.34	11.25	4.23
January ...	3.51	3.55	3.10	5.60	1.99	——	2.83	10.04	1.04
February ..	5.99	2.90	3.75	12.76	0.57	1.80	7.80	1.38	1.42
March.....	1.13	5.40	8.66	16.35	1.15	5.77	1.39	3.40	6.17
April......	0.98	4.70	2.66	11.96	2.08	6.79	5.75	0.68	1.92
May	0.09	0.48	7.55	1.24	0.16	0.70	0.25	1.25	3.21
June	0.33	1.06	0.00	3 85	0.36	0.00	0.30	0.67	0.00
Sums......	22.21	29.15	37.26	58.09	44.67	——	24.08	30.03	21.80

* November, 1880—One shower, amount assumed to be $0^{\text{in}}.50$. N. B. December, 1884.

Mean annual rainfall (8 years), *July to July* = 33.41 in.

Great Telescope for Los Angeles.

Authentic information regarding the proposed forty-inch refractor for Wilson's Peak is difficult to obtain. A newspaper report of an interview with Mr. A. G. Clark on September 28, recites that one of the discs (now on exhibition at Paris) will probably arrive in Boston in October. The other disc is not yet cast, and M. Mantois is, apparently, not willing to undertake the work without a contract, which is not yet executed. The Trustees of the Fund have, so it is said, authorized Mr. Clark to pay $10,000 for two satisfactory forty-inch discs, which is not an unreasonable price by any means. Mr. Clark offered to make the objective and the mounting for $100,000, during his visit to California in the winter of 1888–9. So far as is now known, the fund available for the telescope does not yet exceed $150,000. Probably $300,000 to $400,000 would build and equip the observatory. E. S. H.

Force of Gravity at Mt. Hamilton and San Francisco.

Mr. E. D. Preston of the U. S. Coast and Geodetic Survey has published his report on gravity determinations in the Pacific Ocean (*Bulletin* No. 11, U. S. C. and G. S., 1889). The force of gravity at Washington being 1.000000, that at San Francisco (Professor Davidson's Observatory) is 0.999854 and at the Lick Observatory it is 0.999544. Determinations of *g* at four stations in the Hawaiian Islands and for a station at Caroline Island are also given. E. S. H.

Lick Observatory Photographs of the Moon.

Knowledge for October 1, 1889, contains an article by the editor (Mr. Ranyard), on the Moon as seen in the Lick Telescope. Excellent reproductions of five silver prints made by the Direct Photo-Engraving Company of London, accompany the article. Mr. Ranyard's remarks upon the temperature of the moon and upon the possibility of the existence of snow-fields on its surface, are well worth close attention. E. S. H.

American Eclipse Expedition to Africa (December 21, 1889).

The New York *Sun*, for October 17, has an account of the sailing of the U. S. S. *Pensacola* with the American Eclipse Expedition to Africa. The expedition is under Professor D. P. Todd, of Amherst College, as chief astronomer. His astronomical assistants are Messrs. Bigelow, Davis and Jacobi. Mr. Carbutt goes as photographer, with Mr. Wright as his assistant; Mr. E. J. Loomis as naturalist; Professor Abbe as meteorologist, with G. E. Van Guysling as assistant; Mr. Preston as the observer of magnetics and for determinations of gravity; Mr. W. H. Brown as osteologist and naturalist, with his brother as assistant; Mr. Orr as ethnologist and ornithologist; H. Chatelaine as interpreter; G. T. Flint as stenographer, and Dr. Bartlett as apothecary! Add to these names that of Professor Alex. Agassiz, who may join the vessel at Cape Town to engage in deep-sea dredging. This is carrying the war into Africa, indeed. The newspaper account of the astronomical outfit is somewhat meagre. It appears that the expedition is provided with a photoheliograph, giving an image of the sun four inches in diameter. With this the partial phases will be photographed on *ortho-chromatic* plates (No. 16) and the total phase on *ortho-chromatic* plates (No. 27). A large mirror, belonging to Professor Langley,

an equatorial belonging to the Harvard College Observatory, and *twenty* cameras are also provided for photography.

It is to be hoped that the expedition will meet with fine weather, in order to utilize its unusually large force of observers and instruments. Sir ISAAC NEWTON said at the death of his pupil COTES, "If COTES had lived, we should have known something." If the four minutes of totality are clear at St. Paul de Loando we shall certainly learn something from these many skilled observers with their large equipment.

It now appears that with two expeditions in Africa, and with two at least, in America, the observation of this eclipse is thoroughly well provided for. It should be a source of gratification to Californians, and especially to this Society, that the generosity of one of our members has allowed the Lick Observatory to put a strong expedition in the field. E. S. H.

October 26, 1889.

ECLIPSE OF *JAPETUS*, THE VIII SATELLITE OF *SATURN*, ON NOVEMBER 1, 1889.

The eclipse of *Japetus* was observed here on November 1 with the twelve-inch equatorial. Only a part of this very rare phenomenon was visible at this point, the interval between the rising of *Saturn* and daylight covering only a small portion of the time occupied by the eclipse, or, rather, series of eclipses; for the satellite passed through the shadow of the entire ring system as well as that of the globe of *Saturn*. The satellite would first pass into the outer edge of the shadow of the ring, and would next appear in the sunlight, shining through the CASSINI division, being visible for probably eighteen minutes. It would then pass into the shadow of the inner bright ring; from this it would emerge in the semi-shadow of the Crape Ring, from which it would pass into the sunlight again between the shadow of the Crape Ring and that of the ball. It would next enter the shadow of the ball, and, from this point on, a reversal of all the first phenomena would happen. The entire series of eclipses covered a period of approximately nineteen hours. That portion of the eclipse which could be seen from the Lick Observatory was the reappearance from the shadow of the globe and passage through the semi-shadow of the Crape Ring into the shadow of the inner bright ring.

The important questions in connection with this phenomenon

were: Would the satellite become visible when it came to the projection of the CASSINI division? What would be the effect of the Crape Ring upon the appearance of the satellite?

The last question only could be answered from this point, as the satellite would rise eclipsed in the shadow of the ball, and not reach the second part of the CASSINI division until long after sun-up.

Carefully watching the point of reappearance of the satellite, it was faintly caught at $14^h\ 38^m$ Mt. H. m. t. It reappeared quite close to the satellites *Tethys* and *Enceladus*. It grew pretty rapidly brighter, and attained its full brightness at about $14^h\ 50^m$. It was then about 0.1 magnitude less than *Tethys*. The proximity to these two satellites gave an excellent means of detecting changes in its brightness by comparison with their light. Eighty such comparisons were made, and from these I have constructed a curve, which very clearly shows what effect the Crape Ring had upon the appearance of the satellite. *Japetus* required a little over ten minutes to become wholly free from the shadow of the ball. After remaining at its full brightness for fifteen minutes, it began very slowly to decrease in light; however, changing less than 0.1 magnitude in forty minutes' time. At $15^h\ 54^m$ the light began to decrease more rapidly, and in sixty-five minutes it passed through 0.7 of a magnitude. It then approached the shadow of the inner bright ring, and in fifteen minutes its light diminished 0.66 of a magnitude, when it totally disappeared, at $17^h\ 11^m\frac{1}{2}$.

These observations show us that, after striking the sunlight shining through between the ball and the rings, the satellite then passed into the shadow of the Crape Ring, which sensibly affected its brightness. Passing deeper into this *shade*, the absorption of the sunlight became more and more pronounced, until finally the satellite struck the shadow of the inner bright ring, which it rapidly entered and within which it disappeared.

These observations, therefore, tell us that the Crape Ring is truly transparent—the sunlight sifting through it; that the particles composing the Crape Ring cut off an appreciable quantity of sunlight; that these particles cluster more and more thickly—or, in other words, the Crape Ring is denser as it approaches the bright rings.

Observations made elsewhere will tell us whether the satellite was seen when it entered the projection of the CASSINI division. The observations will be published in full in the *Monthly Notices* of the Royal Astronomical Society. E. E. B.

MT. HAMILTON, Nov. 6th, 1889.

Parabolic Elements of Comet Swift (Nov. 16).

By A. O. Leuschner.

From the three successive observations at Lick Observatory, November 20, 21, 22, which were kindly communicated to me by Professor E. E. Barnard, I have deduced the following parabolic elements by Oppolzer's method:

$$T = 1889, \text{ Dec. } 11, 8493 \text{ G. M. T.}$$
$$\Omega = 306^\circ\ 25'$$
$$\omega = 116^\circ\ 24' \qquad \text{O} - \text{C} \begin{cases} d\,\lambda, \cos\beta = +1'.2 \\ d\,\beta \qquad\quad = \pm 0.0 \end{cases}$$
$$i = 6^\circ\ 47'$$
$$\log q = 0.0633$$

The small geocentric arc and the error of 1′.2 remaining in λ render these elements extremely uncertain. The comet is very likely periodic.

Berkeley, Cal., November 27, 1889.

Minutes of the Meeting of the Board of Directors, held November 30, 1889, at 408 California Street, San Francisco.

A quorum was present.

The minutes of the last meeting were read and approved.

Bills presented by the Secretary and Treasurer were approved.

Miss C. W. Bruce, of New York City, was duly elected a life member, subject to the action of the Society.

Adjourned.

Minutes of the Meeting of the Astronomical Society of the Pacific, held November 30, 1889 (by Invitation), in the Rooms of the California Academy of Sciences, San Francisco.

[Prepared by the Secretaries for Publication.]

Owing to the absence of the President, Vice-President Pierson took the chair.

The thanks of the Society were tendered to the California Academy of Sciences for the use of their rooms.

The minutes of the last meeting were read and approved.

A list of gifts to the Society was read, and thanks were returned to the donors.

Plate I

Jupiter.

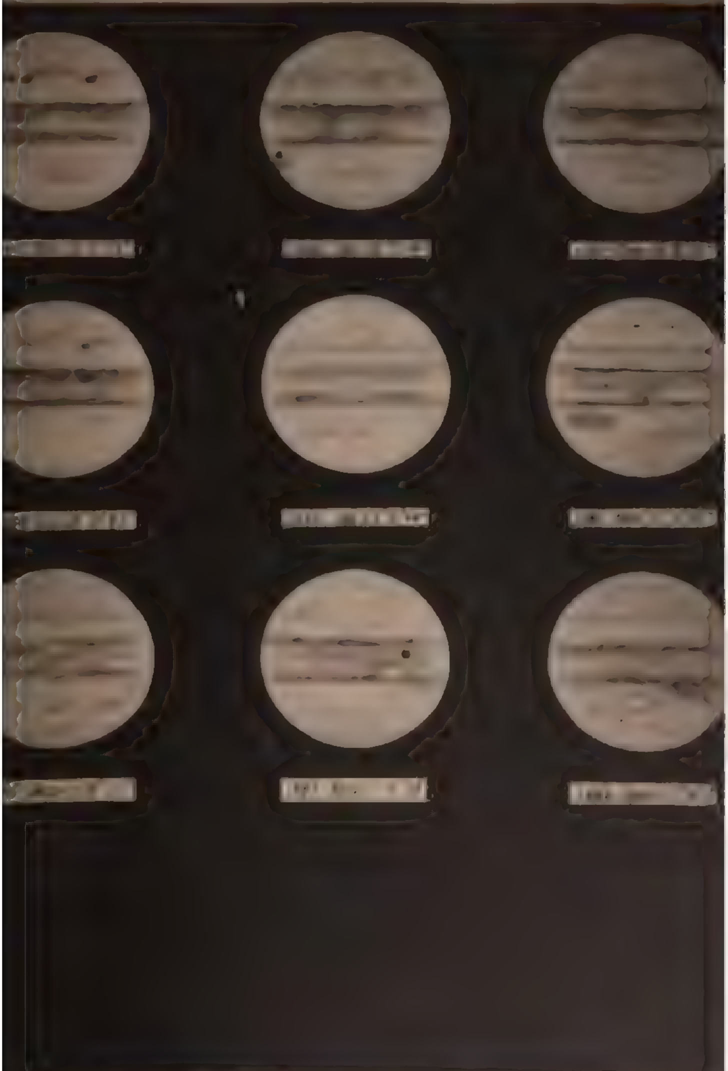
Plate II

Jupiter.

Plate III

Jupiter.

Plate IV



Jupiter.

The following members were then elected; the names of life-members, duly elected by the Board of Directors, being marked with a star (*):

CHARLES S. AIKEN, - - - - -	Berkeley, Cal.
J. H. C. BONTÉ, D. D. - - - -	Berkeley, Cal.
Miss C. W. BRUCE,* - - - - -	39 East Twenty-third Street, N. Y. City.
N. E. BECKWITH, - - - - - -	Los Gatos, Cal.
J. A. BRASHEAR, - - - - - -	Allegheny City, Penn.
CHARLES M. BAKEWELL, - - -	Berkeley, Cal.
Miss AGNES M. CLERKE, - - -	68 Redcliffe Square, London, England.
Hon. HORACE DAVIS, - - - -	1011 Bush Street, San Francisco, Cal.
A. B. DEPUY, - - - - - - -	216 North Sixth Street, Camden, N. J.
WARREN B. EWER, - - - - -	220 Market Street, San Francisco, Cal.
Mrs. MARTHA MCC. EWER, - -	220 Market Street, San Francisco, Cal.
JOHN GAMBLE, - - - - - - - -	Laurel Hall, San Mateo, Cal.
HENRY HARRISON, - - - - - -	South Bergen, N. J.
CHARLES F. HART, - - - - -	N. Temescal, Alameda County, Cal.
O. C. HASTINGS, - - - - - -	Box 166, Victoria, B. C.
JOHN J. HERR, - - - - - - - -	438 California Street, San Francisco, Cal.
WHITNEY HERR, - - - - - - -	438 California Street, San Francisco, Cal.
FRANK JAYNES, - - - - - - -	W. U. Telegraph Co., San Francisco, Cal.
Rev. GEORGE W. JAMES, F. R. A. S.,	Oleander, Fresno County, Cal.
AUGUSTUS F. KNUDSEN, - - -	Box 2139, Boston, Mass.
Professor JOSEPH LE CONTE, - -	Berkeley, Cal.
Miss MARGARET LEPPER, - - -	Box 490, Benecia, Cal.
WARREN OLNEY, - - - - - - -	481 Prospect Avenue, Oakland, Cal.
JAMES N. PEMBERTON, - - - -	Downey, Cal.
C. D. PERRINE, - - - - - - -	211 Clay Street, San Francisco, Cal.
J. E. RICHARDS, - - - - - - -	Los Gatos, Cal.
F. B. RODOLPH, - - - - - - -	969 Washington Street, Oakland, Cal.
WM. G. RAYMOND, - - - - - -	Berkeley, Cal.
Professor J. K. REES, - - - -	Observatory of Columbia College, New York City.
WM. F. SMITH, - - - - - - - -	2515 Broadway Street, San Francisco, Cal.
GARRETT P. SERVISS, - - - - -	8 Middagh Street, Brooklyn, N. Y.
J. A. SLADKY, - - - - - - - -	Berkeley, Cal.
IRVING M. SCOTT, - - - - - -	507 Harrison Street, San Francisco, Cal.
JOHN H. YOELL, - - - - - -	San José, Cal.

The Secretary's books show that the Society now consists of 156 active and 22 life members, or 178 in all. Mr. PIERSON announced to the Society that Hon. ALEXANDER MONTGOMERY, a member of the Society, offers the sum of $2500 to the Astronomical Society of the Pacific, for the purpose of establishing a gold medal to be awarded annually to the writer of the best paper on the subject of Astronomy presented to the Society during the year; the gift to be without conditions, and the Society to have the privilege of using this gift for other purposes. The Society accepted this generous gift by a rising vote.

A paper "On the Determination of the Relation between the Exposure Time and the consequent Blackening of a Photographic Film" was then read by Mr. LEUSCHNER. This was followed by a paper "On Photographs of the Milky Way," by Mr. BARNARD. The latter paper was illustrated by lantern slides prepared by Mr. BARNARD from some of his own negatives. The other papers announced for the evening were not read.

The Society then adjourned to meet at its rooms, 408 California Street, on January 25, 1890.

OFFICERS OF THE SOCIETY.

EDWARD S. HOLDEN (Lick Observatory),	*President*
WM. M. PIERSON (76 Nevada Block, S. F.), W. H. LOWDEN (213 Sansome Street, S. F.), FRANK SOULÉ (Students' Observatory, Berkeley),	*Vice-Presidents*
CHAS. BURCKHALTER (Chabot Observatory, Oakland), J. M. SCHAEBERLE (Lick Observatory),	*Secretaries*
E. J. MOLERA (850 Van Ness Avenue, S. F.),	*Treasurer*

Board of Directors—Messrs. ALVORD, BOERICKE, BURCKHALTER, GIBBS, GRANT, HOLDEN, LOWDEN, MOLERA, PIERSON, SCHAEBERLE, SOULÉ.

Finance Committee—Messrs. GIBBS, PIERSON, MOLERA.

Committee on Publication—Messrs. DEWEY, TREAT, ZIEL.

Committee on the Comet Medal—Messrs. HOLDEN (*ex-officio*), SCHAEBERLE, BURCKHALTER.

NOTICE.

Members are requested to preserve the copies of the Publications of the Society as sent to them. Once each year a title page and index of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume.

It is intended that each member of the Society shall receive a copy of each one of the Publications for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied.

Complete volumes for past years (preceding the calendar year in which any member was elected) will also be supplied to members, so far as the stock in hand is sufficient, on the payment of one dollar to either of the Secretaries.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," at the rooms of the Society, 408 California Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS

OF THE

ASTRONOMICAL SOCIETY

OF THE PACIFIC.

(FOUNDED FEBRUARY 7, 1889.)

VOLUME II.

1890.

SAN FRANCISCO:
PRINTED FOR THE SOCIETY.
1890.

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Publications No. 10 (September 13, 1890).

Publications No. 11 (November 29, 1890).

Publications No. 12 (December 31, 1890).

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

No. 6. SAN FRANCISCO, CALIFORNIA, JANUARY 25, 1890.

NOTE ON THE DENSITIES OF THE PLANETS.

BY DANIEL KIRKWOOD, LL.D.

The major planets *Jupiter*, *Saturn*, *Uranus* and *Neptune*, as well as the sun, have gaseous envelopes of unknown depth. We know little or nothing as to the physical constitution of the asteroids and telescopic satellites. There remain the five bodies, *Mercury*, *Venus*, the *Earth*, the *Moon* and *Mars*. Of the last three the masses, volumes and densities have been determined. *Venus* is less accurately known, and considerable uncertainty still attaches to the mass of *Mercury*. The recent researches of Professor HARKNESS* have suggested the inquiry whether any discoverable order obtains between the relative densities of these five bodies. For the purpose of comparison, let us arrange them in the order of their diameters, with the relative masses and densities resulting from the investigations of HARKNESS:

PLANETS INTERIOR TO THE ZONE OF ASTEROIDS.

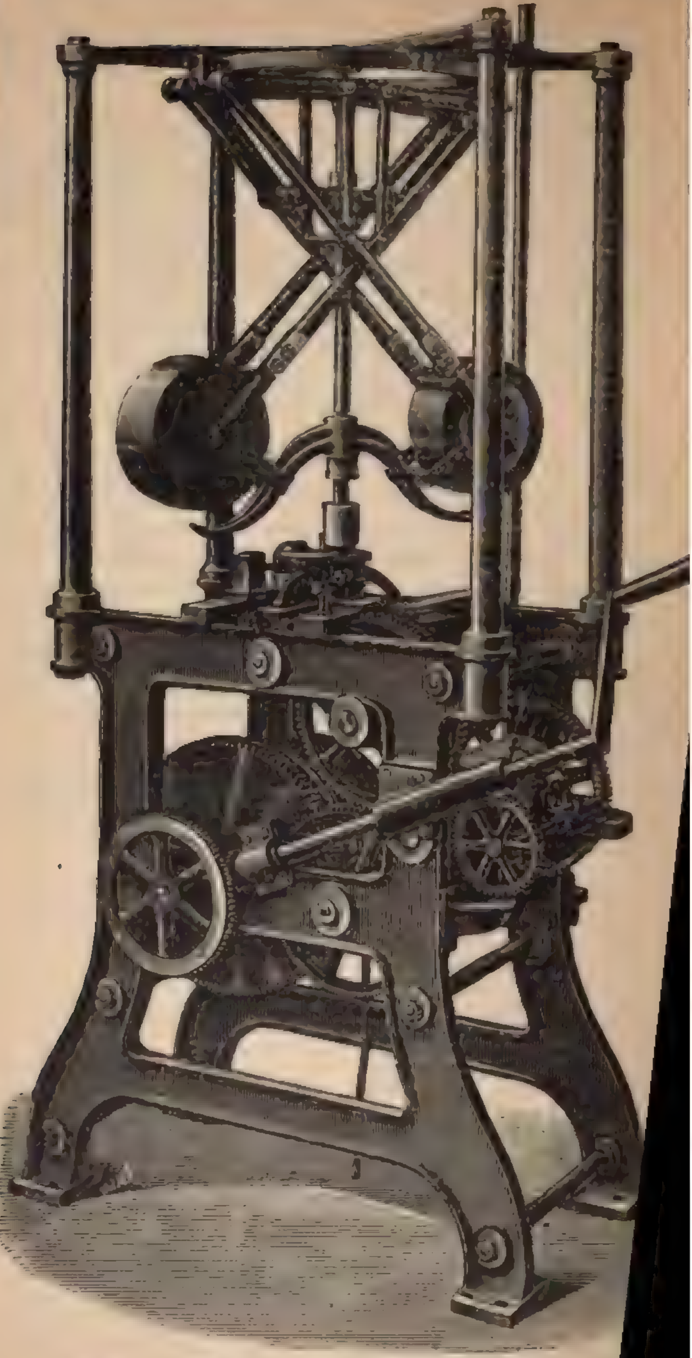
NAME.	MEAN DIAM.	MASS.	MEAN DENSITY.
The Earth	1.000	1.0000	1.000
Venus.....................	0.972	0.8220	0.895
Mars	0.534	0.1076	0.707
Mercury....................	0.382	0.0382	0.683
The Moon	0.273	0.0123	0.610

Adopting the masses obtained by HARKNESS, it follows:

1. That the *Earth* is the most dense of all the planets; and

2. That in every instance a greater mass corresponds, not only to a greater diameter, but also to a greater density. An approximate

* GOULD'S *Astr. Journ.*, No. 194.



DRIVING-CLOCK OF THE THIRTY-SIX-INCH EQUATORI

(By the courtesy of Engineering.)

form of the relation might be given, but the new value of *Mercury's* mass requires confirmation.

ARLINGTON AVENUE, RIVERSIDE, CAL., November, 1889.

N. B.—This note was already in type when the author learned from the *Sidereal Messenger* for December, 1889, (p. 471), that a note on the same subject had been printed in the *American Journal of Science* for November last. It was, however, too late to withdraw the article.

A NEW AND SIMPLE FORM OF ELECTRIC CONTROL FOR EQUATORIAL DRIVING-CLOCKS.

By JAMES E. KEELER.

It is well known that the driving-clocks of equatorial telescopes, which demand a continuous motion, cannot be made to run with the uniform rate which is characteristic of a good pendulum clock; hence, methods are sought for regulating a continuous motion by means of a pendulum. Devices for effecting this mechanically have not been successful, where great accuracy is required. In such arrangements extra work is necessarily thrown upon the pendulum, which is prevented from swinging freely, and is then no longer isochronous. By means of electricity, however, the control can be effected without detrimental reaction on the pendulum.

For a description of the ingenious devices which have been invented for controlling driving-clocks electrically, the reader is referred to a pamphlet by Sir HOWARD GRUBB,* describing four different systems which have been tried or are actually in use.

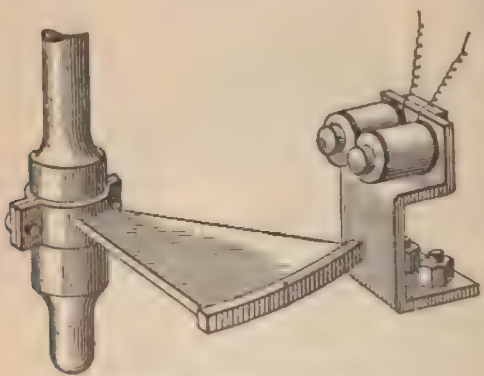
The driving-clock of the 36-inch equatorial of the Lick Observatory is of the same form as the smaller driving-clocks by WARNER & SWASEY, with a few modifications, made necessary by its unusual size and weight. The governor-balls weigh sixty pounds each, and their centers of figure and gravity are not coincident; so that the regulation for rate may be effected by turning the balls on their axes. The vertical shaft of the governor rotates once a second. One of the clock-arbors, which rotates in one minute, has been converted into a chonograph by the makers, an extremely convenient arrangement, since it gives a means of studying the performance of the machinery by an astronomical clock, without direct reference to the heavens.

* On the Latest Improvements in the Clock-driving Apparatus of Astronomical Telescopes. By Sir HOWARD GRUBB, Inst. of Mech. Eng., London, 1888.

The driving-clock is of excellent workmanship, and its rate is sufficiently uniform for micrometer measurements and all the ordinary purposes of an equatorial. For photographic and spectroscopic work the makers provided an electric control, which, on trial, was found not to work satisfactorily, as it communicated a jar to the telescope.

In the *Scientific American* for November 10, 1888, I described a simple form of electric control which was designed to remedy this defect. As the same device, with slight modifications, is still in use, I quote in part the description there given:

"A soft iron sector, subtending an angle of 36°, and having a radius of six inches, is clamped to the vertical axis of the governor, and rotates in a horizontal plane. The sector passes very close to the poles of an electro-magnet (part of the old control), which is mounted on a slightly elastic standard of steel.



ORIGINAL DESIGN OF CONTROL.
(By the courtesy of *The Scientific American*.)

At every second a strong current is sent through the coils of this magnet by means of a standard clock, the circuit being closed, as in the case of the old control, by the relay points of the chronograph attached to the driving-clock. The driving-clock is set so as to run a little too fast, and when the governor is started the sector continually gains upon the click of the chronograph until it reaches the magnet of the control, when the friction produced by the attraction of the latter prevents any further acceleration, and the governor will rotate in exactly one second by the standard clock as long as the control is in operation.

"The elasticity of the support on which the electro-magnet is mounted plays an important part in the proper working of the control. When the sector passes at the exact instant of the passage of the current, the magnet springs in toward the sector and comes in *actual contact* with it, very greatly increasing the friction, while the

passage of the sector at any other instant meets with no resistance, the magnet being slightly withdrawn by its support.

"The current used with the control is obtained from a battery of twenty* gravity cells, employed during the daytime in transmitting time signals to San José. As the signals are not sent at night, the battery is then connected with the control by turning a switch. With this control no shock is communicated to the telescope, and the image of a star is steady."

The apparatus described above was used for some time, and found to be satisfactory in every respect but one; it was not quite powerful enough to hold the governor with certainty within the greatest range of accidental variation of rate. The radius of the sector, six inches, had been chosen at random, without any guide to indicate the proper dimensions. Another sector was, therefore, made, with a radius of 8½ inches, and put on in place of the old one, the apparatus being otherwise exactly as before. The control then worked perfectly, and has been used ever since with entire satisfaction.

Professor Howe, of Denver, while visiting the Lick Observatory last winter, suggested an improvement which is apparently an excellent one, although circumstances do not admit of its application to the 36-inch equatorial, and I have represented it in the accompanying diagram. (See plate.) With the existing arrangement, some little attention is necessary to get the sector in the proper part of its orbit when the current passes. The governor is first started at full speed, and then, if necessary, slowed down by hand until the sector falls within range of the magnet at the beat of the chronograph; otherwise much time would be consumed in waiting for the governor to gain the necessary distance. If the magnet were movable about the axis of the governor, it could at once be set to the proper position after the governor had attained its maximum speed, and held there by a clamp. Such an arrangement is shown in the diagram. For the sake of clearness, the wires bearing the current are not shown beyond the control magnet, but it would evidently be very easy to lead the current through the central pivot, the connecting-bar and the circular track for the clamp, leaving the arm free to rotate in either direction. A further description of the diagram seems to be unnecessary.

This control may, at first view, appear to be somewhat "brutal" in principle, and liable to produce vibrations in the telescope; but

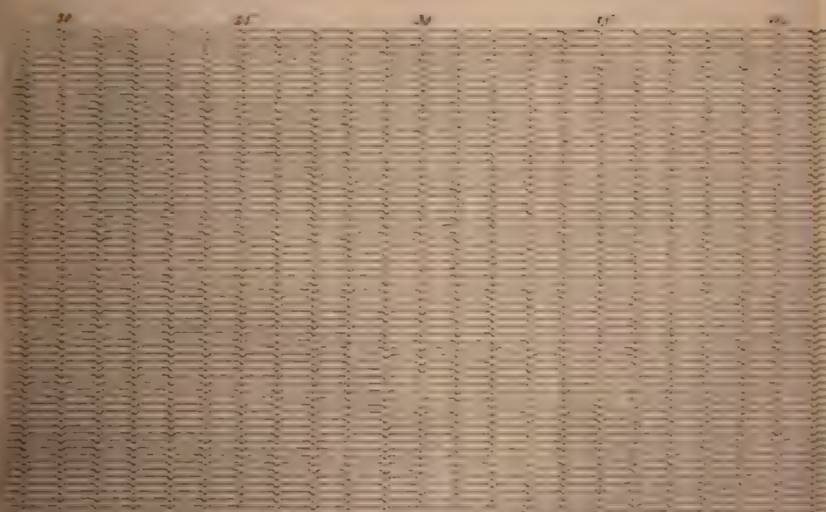
* *Eighteen cells are in use at present (November, 1889).*

experience shows that a practically uniform motion is attained, and a star bisected by a micrometer thread in the field of the telescope does not show the slightest evidence of tremor at the passage of the sector. In a very short time after starting the driving-clock the sector settles down into a certain position relative to the magnet, which it preserves as long as the current passes. This position is found to be a little *behind* the magnet, so that the circuit is broken before the full retarding force comes into play. It will be noticed that, as in other effective controls, the friction is applied gradually, and nearly in proportion to the amount of the error to be corrected. In the particular case of the Lick Observatory driving-clock the action is necessarily vigorous, on account of the great momentum of the governor. The amount of the friction is easily regulated by varying the battery power.

A photographic reproduction of part of a chronograph sheet (reduced to about one-half) is shown under the diagram, and illustrates the action of the control better than any description. It contains no error greater than $0^s.01$. It may be noted that since the same clock is employed to operate the control and to record on the chronograph, the seconds columns on the sheet are strictly parallel to the axis of the chronograph barrel, no matter what the rate of the standard clock may be, for the angular velocities of the pendulum axis and chronograph barrel are always as 60 : 1, and the governor rotates once for each beat of the pen. When different clocks are employed for controlling and for marking, the columns are inclined by an amount depending upon the difference of the rates of the two clocks, an amount too small, however, in any ordinary case, to be appreciable by the eye.

It has been shown above that the governor shaft of the driving-clock can be made to rotate with uniform velocity in one second by a standard astronomical clock. Whether the polar axis will rotate with a correspondingly uniform motion will depend upon the perfection of the gear-cutting in the intermediate parts of the train. Two of the controls described by Sir Howard Grubb have the advantage of applying the necessary corrections close to the screw which drives the great wheel on the polar axis, and thus avoiding the errors of several pairs of gears. For long exposures in photography, particularly with very large telescopes, correction by hand* is imperative,

*In the 36-inch refractor of this Observatory, and the 5-foot reflector of Mr. Common, this correction is not made by moving the telescope, but by moving the photographic plate, which is mounted on double slides and moved accurately by fine screws.



since no automatic contrivance can allow for the errors caused by change of refraction and flexure, and absolutely uniform rotation of the polar axis is of less consequence. It is sufficient if the errors of the clock-work are small, and are not cumulative, as they are apt to be without control by a standard clock.

It is not easy to say how readily this control could be applied to smaller instruments. The governors of driving-clocks seldom rotate so slowly as once a second, but the control could evidently be applied to any shaft rotating in an integral part of a second. The sector might also require to be balanced by a counterpoise, or two diametrically opposite sectors and magnets could be used. For large telescopes, experience at this Observatory has shown that the control is perfectly efficient.

A method for bringing the control of the Lick telescope rapidly into action, and applicable under existing arrangements, occurred independently to Professor HOLDEN and myself, and will be given a trial. Four equidistant sectors, each consisting of a block of soft iron, are enclosed between two circular discs of thin sheet brass, the axis of the governor passing through the center. The sector nearest to the magnet will then come first into action, the others being inoperative, and the governor will never have to gain more than one-fourth of a revolution; the chances are that a gain of less than one-fourth will be required.

DETERMINATION OF THE RELATION BETWEEN THE EXPOSURE-TIME AND THE CONSEQUENT BLACKENING OF A PHOTOGRAPHIC FILM.

BY ARMIN O. LEUSCHNER.

For some time past it has been the custom at the Lick Observatory to standardize photographic plates on which photographs of celestial objects had been secured. The process of standardizing a plate consists in exposing some portion of it, previously protected against the light of the object, to the light of a standard-lamp through a small square aperture. On development the plate will show a more or less dark square, due to the light of the lamp. In all cases a series of squares is secured on the plates, the times of exposure being either 1^s, 5^s, 10^s, 20^s, 30^s, *etc., or* 1^s, 2^s, 4^s, 8^s, 16^s, etc., according to cir-

cumstances. The various parts of the image of the object are then matched with the different squares, and thus the actinic intensity of the object can be found in terms of the intensity of the standard-lamp; the unit of light being the amount of light received through an aperture, one mm. in radius, one m. distant, in one second. If this unit has once been ascertained in terms of the intensity of any celestial object, we may refer all our results to the intensity of that object, as the Moon, or *Polaris*, for example.

It was after the Total Solar Eclipse of the year 1886, that Mr. W. H. PICKERING, of the Harvard College Observatory, for the first time exposed some eclipse-plates to a standard-lamp, with a view of determining the actinic intensity of the corona and the surrounding sky. The circumstances under which Mr. PICKERING was compelled to try his experiment were most unfavorable. Besides the eclipse-plates, another plate was standardized, in order to secure the true intensities for the various exposure-times, as it was feared that the eclipse-plates had suffered from exposure to a damp climate. In fact, Mr. PICKERING found that there *was* a difference in the intensities of the squares on the two plates, for he says:

"On comparing the standard squares with those upon the eclipse-plate, the latter were found to be considerably weaker, the denser squares showing the falling off more than the fainter ones. This may have been due in part to the original difference in the sensitiveness of the plates, but I think it may very likely have been caused by the heat and moisture to which the eclipse-plates had been exposed."

What I wish to dwell upon here is the assertion that the difference in the intensities of the squares *may* have been due to an original difference in the sensitiveness of the plates. In fact, we shall soon see that a difference in sensitiveness does not only exist in different plates of a certain species, but even in the various parts of the *same* plate.

To reduce the intensities of the various squares to any adopted unit, it is necessary to know the relation between the time of exposure and the consequent blackening of the photographic film,—the law according to which the intensities of a square increase with the exposure times. It is generally assumed that the intensity is directly proportional to the exposure time,—that is to say, a square exposed for four seconds will be twice as dark as one exposed for two seconds only. In a recent paper, presented before the B. A. A. S. meeting

of 1889, Capt. ABNEY reported that his experiments showed that intensity was proportional to the time, without limitations. Following the example of Mr. PICKERING, the Lick Observatory eclipse-plates at the Total Solar Eclipse of January 1st of this year were all standardized, and it was (on the authority of Capt. ABNEY) assumed that intensity varied as exposure-time, in the reductions of the Lick Observatory Eclipse Report. Whatever may be the law for a certain species of plates, the intensity will be a function of the corresponding exposure-time, or

$$I = \phi(t)$$

If we could assume that the relative increase in the intensity of a square with the time was the same for all plates of different sensitiveness, then for any other species of plates the law is

$$I = m(\phi)\,t$$

where m is the ratio of the intensities of any two standard-squares, exposed for the same number of seconds on the plates of the first and second species. As this is not as yet an established fact, it is advisable in all photometric work to confine one's self to one special species of plates. At the Lick Observatory the Seed-plates No. 26 are commonly used.

If we could assume that all the Seed-plates No. 26 were exactly alike, we might compare any square of any plate a of this species with any other square of any other plate b. But I have found that a square of a, exposed for t seconds, does not, in general, show the same intensity as a square of b, exposed for the same length of time. We may, however, confine ourselves to one single plate a, and then to another single plate b, and discover the law for each separately. And by taking a sufficient number of plates, and by combining the results suitably, we may come very near to the true relation of the time of exposure, and the consequent blackening of the film of this special species of plates.

Attacking the problem in this manner, I first took up some of the eclipse-plates of January 1st of this year.

Before going any further, it is necessary to say a few words about the method employed in comparing the standard-squares of a plate with each other. Let α and β be any two squares. To compare α and β all the remaining portions of the plate are covered with black cardboard. The plate, being fastened to a stand, is then set up, with the sky near the horizon as a background, and the BRASHEAR wheel photometer of the Lick *Observatory* (for a description of this instru-

ment, see the Lick Observatory Eclipse Report, pp. 84–85,) is placed between the eye and the brighter square of the two. The reading of the scale divided by one hundred gives the ratio of the photographic intensities of the two squares for that background. In order to avoid systematic errors in investigating the relative intensities of a series of squares, a square darker than the entire series should be selected as a comparison-square, and every square of the series should then be reduced to the comparison-square, by means of the photometer. Practically, only about four successive squares of our series lie within the range of the photometer. In order to compare the remaining darker squares of a series, we must invert the process and reduce the intensity of the comparison-square successively to that of every one of the remaining squares of the series. I have found that this process is subject to systematic errors. In order to avoid these errors, a standard-plate was specially exposed by Mr. BARNARD, according to a plan suggested by my previous trials. There are six groups, or sets, of standard-squares on this plate, each set containing four squares. Thus the first set contains exposures of 1, 2, 4, 8 seconds, the second exposures of 2, 4, 8, 16 seconds, the third of 4, 8, 16, 32 seconds, and so forth. The darkest square of each set (longest exposure) is the comparison-square for that set. It is easily seen that by eliminating the comparison-square from each set, any systematic errors arising from the change of the comparison-square and the choice of the background are avoided.

So far, the errors due to the difference in sensitiveness of various portions of the same plate had not been considered in the investigations. As a matter of fact, on all the plates previously observed there was only one square of one-second exposure, only one 2^s square, etc., and it did not suggest itself to me that the errors in these squares might be so large as to seriously affect the results. When, however, I took up the standard-plate just described, I at once saw that quite a difference exists between the intensities of the various squares of the same exposure-time, and it became necessary to take into account the probable errors of the intensities of the different squares. The following is the course taken in investigating this plate:

First, all squares of the same time of exposure,—as, for instance, all 8^s squares—were compared with a certain other square, the mean (denoted by the subscriptum ($_0$) as 8_0^s) taken, and the probable error of the mean determined. The difference in intensity of the different *squares* was surprising. Some squares were found to be from two to

three times as dark as others, exposed for the same length of time. To illustrate this, the comparisons of the 8^s squares are given here. In the following table $\frac{8_I}{32_{III}}$ = ratio of darkness of the 8^s square of the first set to that of the 32^s square of the third set. The numbers represent per cents., or, what is the same thing, the denominators are supposed to be equal to 100. The numbers in brackets represent the number of comparisons.

TABLE I.

Probable Error of an 8^s Exposure.

$\frac{8_I}{32_{III}}$	=	12.0 ± 0.3	(10)
$\frac{8_{II}}{32_{III}}$	=	8.4 ± 0.1	(5)
$\frac{8_{III}}{32_{III}}$	=	16.5 ± 0.2	(5)
$\frac{8_{IV}}{32_{III}}$	=	10.1 ± 0.3	(4)
$\frac{8_0}{32_{III}}$	=	11.8 ± 1.2	

From this we see that the 8_{III}^s square is twice as dark as the 8_{II}^s square, and we also find that even the mean of the four squares or the 8_0^s square has a propable error of 10%. In some cases this amounts to as much as 15%. The probable error of comparison might altogether be neglected in comparison with that of the square itself. This difference of intensity is due to changes in the sensitiveness of the film in different parts, as well as to changes in brightness of the standard flame. The nature of the background and the choice of the comparison-square cannot account for it, these being the same throughout the foregoing comparisons. Next, each of the six groups or sets of our standard-plate was taken up separately and compared with the comparison-square of that set. Each observation was then reduced to the corresponding mean square by multiplying by the ratio $\frac{\text{mean square}}{\text{square}}$. Thus, if in the first set we found $\frac{4_I^s}{8_I^s} = a$, then $\frac{4_0^s}{8_I^s} = a \times \frac{4_0^s}{4_I^s}$. We must remember that the numbers thus obtained do not necessarily express the absolute ratio of a certain square to the comparison-square, since a change of the comparison-square involves systematic errors. Hence, in each set the comparison-square was eliminated by taking ratios. It *is for this reason* that the results, so far obtained from

this plate, extend only to 32^s, since sets V and VI could not be compared by this method without introducing large errors of observation.

It seemed desirable to express the results obtained from sets I–IV absolutely in terms of some unit. An 8^s square occurred in each of the four sets, and after the 8^s square of each set had been reduced to the 8_0^s square every observation could be expressed in terms of the 8_0^s square—that is, in terms of the mean blackness of all the 8^s squares. Thus I supposed this square to contain 8 units, and then found the number of units contained in the other mean squares from each set. In doing this, I did not consider the single 1^s square of this plate, as it evidently was afflicted with a large error, being darker than the 2_0^s square. No systematic errors remain in these results, as the unit is independently determined for every set.

The following are the results of the investigations of this standard plate:

TABLE II.

Results from Standard Plate No. 1.

SET I.	SET II.	SET III.	SET IV.
Units.	Units.	Units.	Units.
$2_0^s = 2.1 \pm 0.3$	$2_0^s = [3.6 \pm 0.4]$	$4_0 = 4.7 \pm 0.6$	$8_0 = 8.0 \pm 0.0$
$4_0^s = 4.3 \pm 0.5$	$4_0^s = 3.8 \pm 0.2$	$8_0 = 8.0 \pm 0.0$	$16_0 = 10.7 \pm 2.2$
$8_0 = 8.0 \pm 0.0$	$8_0^s = 8.0 \pm 0.0$	$16_0 =$ (?)*	$32_0 = 14.6 \pm 2.6$

The law that the blackening of the film is proportional to the exposure-time is therefore confirmed within the limits of two seconds and eight seconds (within the limits of the accidental errors). On this plate the law no longer holds good after 8^s; the proportions fall off after that time. The exact nature of the curve could, of course, not be determined from the IVth set alone (on account of the large probable error remaining in the results).

After having determined the law for this special plate, I compared the observations previously made on other plates with the results just obtained, in order to test their validity. Only those observations were considered which could be freed from systematic errors. As before, in each series, the 8^s square was supposed to contain 8 units, and the other squares were then expressed in the same unit. It will be remembered that the results obtained from

* A wrong square was probably observed. The observation could not be repeated, on account of my absence from the Lick Observatory.

the first plate were gotten by using the mean of four squares, in almost all cases; but on the other plates we have only one square for every exposure-time. Hence (neglecting other circumstances), we must attribute to the results obtained from these other plates probable errors, which are at least twice as large as those found for the results of our standard-plate.

The results obtained from four plates are given in Table III. In one case, the value for the intensity-ratio $\frac{64^s}{128^s}$ has been added, it being impossible to express these squares in our unit without making additional comparisons; in another case the observed value for the relative intensities $\frac{16^s}{32^s}, \frac{32^s}{64^s}, \frac{64^s}{128^s}$ have been added. These ratios are free from systematic errors among themselves, but cannot as yet be combined with the remainder of the series without introducing them again. They contain, however, the errors arising from the errors of the squares themselves.

TABLE III.

Results from Four Plates.

	Standard Plate No. I.	Absorption Co-eff. Plate. June 10, 1889.	VOIGHT. B. Eclipse-Plate, Jan. 1, 1889.
	Units.	Units.	Units.
1^s	......	1.9 ±	......
2^s	2.1 ± 0.3	2.5 ± 0.6	2.1 ± 0.6
4^s	4.3 ± 0.5 3.8 ± 0.2 4.7 ± 0.6	4.2 ± 0.8	4.0 ± 0.8
8^s	8.0 ± 0.0 8.0 ± 0.0 8.0 ± 0.0	8.0 ± 0.0	8.0 ± 0.0
16^s	10.7 ± 2.2	19.2 ± 4.4	$\frac{16^s}{32^s} = \frac{24.0}{55.2}$
32^s	14.6 ± 2.6	51.0 ± 5.2	$\frac{32^s}{64^s} = \frac{19.6}{24.0}$
64^s	......	$\frac{64^s}{128^s} = \frac{13.2}{20.3}$	$\frac{64^s}{128^s} = \frac{8.4}{12.6}$
128^s	......	......	......

VOIGHT. C. Eclipse-Plate, Jan. 1, 1889.	
	Units.
3^s	2.5 ±
4^s	3.2 ±
5^s	3.8 ±
6^s	5.2 ±
7^s	6.9 ±
8^s	8.0 ±
9^s	8.1 ±
10^s	9.0 ±
11^s	9.5 ±

In every one of the four plates we found the law between 2^s and 8^s most strongly confirmed, and can now establish its validity for all the Seed-plates No. 26 (within the limits of the probable errors). Beyond 8^s the results obtained from our first plate are corroborated in the last plate only. In the second plate the proportionality goes as far as 16^s, and in the third even to 64^s, but in *no case does the proportionality go beyond* 64^s.

The results so far obtained are, in toto:

For the Seed-plates No. 26, the blackening of the film is proportional to the time of exposure within the limits of 2^s *and* 8^s, *and may be so as far as* 64^s, *but there is a* [strong] *probability that the proportions fall off after* 8^s.

In order to determine the exact position of the limit at which the proportionality begins to fall off, additional plates will be exposed according to a plan which will enable us to compare the darker squares, also, without introducing large errors. Between 2^s and 8^s, however, the evidence for the validity of the law is already sufficient.

BERKELEY, CAL., November, 1889.

THE LUNAR CRATER AND RILL—*HYGINUS.*

BY EDWARD S. HOLDEN.

[ABSTRACT.]

I have asked Mr. BARNARD to make positive enlargements on glass of one of our best Moon negatives. A negative of August 14, 1888 (made by Mr. BURNHAM), has thus been enlarged two times, and shows the Moon, therefore, exactly as it would appear in the principal focus of a telescope 1140 inches, or 95 feet, long.* I find that I can use on this positive an eye-piece of one inch equivalent focus as a magnifier. That is, it is practicable to examine the lunar surface under perfect conditions of definition and illumination, and under a magnifying power of more than 1100 diameters, or, as if viewed by the naked eye, at a distance of 217 miles or so. This can be done whenever one pleases, and as long as one pleases.

As a test of the excellence of definition, I may mention a discovery which I have made on Mr. BARNARD's enlargement. It is well known that MAEDLER (and others) have mapped the walls of the

* The focus of our photographic lens is 570.2 inches.

Hyginus rill crossing the floor of the *Hyginus* crater. So far as I know, this has only been once seen. The observation is a delicate one, and could only be made when the sun is shining nearly in the direction of the preceding branch of the rill. The walls inside the crater are hardly more than 2000 *yards* apart, and their bright tops are not more than 200 to 220 *yards* wide. Yet they are plainly and obviously visible in this enlargement.

From this single example (among many others which could be given), it is possible to form a judgment of the results which a competent selenographer could draw from a series of our Moon negatives. I have no hesitation in saying that a two or three years' study of such a series would produce greater results than all the previous work of observers in this line, great as these results have been. Unfortunately, the limited force at the Lick Observatory will not permit us to undertake anything more than the production of the negatives themselves. By depositing sets of these at certain scientific centers, they will be sure, sooner or later, to be studied by competent observers who have the necessary leisure.

PHYSICAL OBSERVATIONS OF *JUPITER* IN 1889.

By J. E. Keeler.

[Abstract.]

Mr. Keeler exhibited a series of twenty-four drawings of *Jupiter*, made during the opposition of 1889, with the thirty-six-inch equatorial of the Lick Observatory. The drawings were made on a large scale, the elliptical outline of the planet being 3.50 × 3.30 inches, and were intended to show all the details that could be perceived with the telescope and transferred to paper in the limited time allowed by the rotation of the planet, (about fifteen or twenty minutes). All dimensions were mere eye estimates, but they had been checked by micrometer measurements and found to be fairly accurate. Reference was made to the extremely satisfactory views obtained with the great telescope and a *résumé* given of the different kinds of astronomical work in which the instrument had proved to be efficient.

The equatorial zone of *Jupiter* was brilliant white at the edges, with a salmon-pink central stripe, which the measurements showed to be a trifle south of the equator. From the edges of the zone

long streamers projected at certain places into the red belts, with which they eventually became parallel, and gradually becoming more diffuse, were lost in the general red color of the background. These streamers, which are doubtless the cause of the double and triple appearance of the red belts, often described, were, according to the observations, masses of clouds projected outward from the equatorial zone, and gradually left behind by the forward drift of that region. Two were frequently seen abreast, but never three. The roots of the streamers were brighter than the average surface of the equatorial zone, and were usually tinged with a curious olive-green color, which seemed to be characteristic of great disturbance. At certain parts of the equatorial zone, the streamers were sometimes considerably distorted, but when long they invariably pointed toward the following limb of the planet. Observations of bright knots on the streamers showed that there was a flow of matter along them from the root outward.

The Red Spot was frequently well seen. It was shorter than in 1881. The color was a pale pink, lighter in the middle of the spot. At the following end, the outline was marked by a faint dark shading.

On a broad, uniformly-tinted, gray belt on the southern hemisphere, following the Red Spot, were many oval and round brilliant white spots, forming one of the most beautiful features of the surface of *Jupiter*. A curious symmetry was often observed in the grouping of these spots, which are shown in nearly all of the drawings.

On the northern hemisphere the details were much simpler, and the belts were of the usual form. Bright white spots like those described above were never seen. As in former years, the greatest activity seems to be manifested south of the equator.

BRIGHT METEOR SEEN JANUARY 1, 1890.

[ABSTRACT.]

Mr. PERRINE gave the following description of a bright meteor seen by him in Alameda, between 10^h and $10^h\ 5^m$ P. M., on January 1st. It first appeared in the northern sky, at an altitude of 35°– 40°, and then moved southward, within 10°– 15° of the zenith, disappearing at an altitude of about 45° above the southern horizon.

The head was very bright, and the long, bright train was fully 45° in length. The train remained visible for five seconds or so. No noise was heard.

C. D. PERRINE.

NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

PHOTOGRAPHIC PHOTOMETRY.

Nature for October 10, 1889 (p. 584), has an abstract of a very important paper by Capt. ABNEY, F. R. S., on this subject, as follows:

"The author concludes, from his experiments, that the deposit of silver made by different intensities of light varies [in density] directly as the intensity of light acting—this, of course, within such limits that reversal of the image is not commenced and that the film is not at any part exhausted of the silver salt which can be reduced."

Experiments by Mr. LEUSCHNER on this same question are printed in the present number. E. S. H.

MR. BRETT ON THE PHYSICAL CONDITION OF *MARS*.

Publications No. 5 of the Society (page 122), contains a *résumé* of a recent paper by M. FLAMMARION, on the physical condition of *Mars*. The fundamental assumption of that paper is that the dark markings on *Mars* represent areas of water. This assumption, while probable, is not yet proved.

A paper by Mr. JOHN BRETT, F. R. A. S., in the *Monthly Notices Royal Astronomical Society* for 1877 (vol. 38, p. 58), on the same subject, has not, it appears, received the attention it deserves.

It is worth while to summarize it here, in order to accent the wide difference of views held by observers of this planet, and because of its suggestiveness in many regards.

Mr. BRETT's conclusions are based on his observations of 1877. He points out, first, that *Mars* does not show the same delicacy of detail as *Jupiter*, for example, under like conditions; and he attributes to *Mars* an atmosphere of considerable opacity on this account. As the details of the planet's surface vanish before they reach the limb, while they are best seen at the center of the disc, and as the disc is brightest at the limb, the conclusion is that the markings themselves are situated below the surface of a tolerably dense atmosphere. The chief topographical features on *Mars* are permanent, and hence the body of the planet is solid. There are few or no

clouds on *Mars*. This fact alone is fatal to the belief that the "land" and "water" on *Mars* act as on the Earth. A whole opposition of *Mars* may pass and no changes of its own atmosphere be made out.

It is certain (from spectroscopic observations) that watery vapor exists in the atmosphere of *Mars*. It does not necessarily follow that the vapor is anywhere condensed into visible clouds. If the polar caps are veritable "snow-caps," then clouds *must* exist in the atmosphere. Chilled water-vapor *must* produce clouds. As no (or few) evidences of clouds exist on the equatorial regions of the planet, Mr. BRETT's conclusion is that the so-called "snow-caps" cannot be snow-fields at all.

All the *dark* markings disappear before they reach the limb of the planet, while the "snow-caps" themselves are best seen at the limb, and often project far beyond it. This projection has been laid to irradiation. Mr. BRETT thinks that the "snow-caps" are, in fact, clouds in the higher and colder regions of the atmosphere. The dark patches near the caps he supposes to be their shadows. He assumes that the regions near the poles are the only ones cool enough to condense the (invisible) water-vapor into visible clouds. Moreover, it follows that the surface of the planet in general is hot—hot enough to make the formation of clouds impossible; and it is likely, consequently, that the "seas" are not water.

Mr. BRETT also points out that ordinary atmospheric absorption will not account for the fact that the central parts of *Mars* are red, while the limbs are "white" (lemon-yellow or yellowish white in the great telescope.) The nature of the absorption at the limb is one of the most difficult points to account for on a theory like that of M. FLAMMARION's, previously cited. Mr. BRETT attempts no special explanation of the differences of color between the "seas" and the "continents,"—nor does he mention the "canals," of course.

The above summary is given, as was said, simply to indicate the wide differences between plausible explanations of the phenomena observed on *Mars*. The fact that such differences of opinion are even possible indicates the unsatisfactory nature of our knowledge of this planet—and we know more of this planet than of any other.

E. S. H.

"THE CHIEF DISCOVERERS OF COMETS."

Mr. W. F. DENNING, in the *Observatory* for November, 1889, gives the following table, which is well worth reprinting. It has been completed to 1890:

NAME OF DISCOVERER.	Period of Observations.	No. of Comets discovered.
CHARLES MESSIER	1760–1798	13
P. F. A. MECHAIN	1781–1799	8
CAROLINA HERSCHEL	1786–1795	6
JEAN LOUIS PONS	1802–1827	30
PADRE DI VICO	1844–1846	5
T. J. C. A. BRORSEN	1846–1851	5
WILHELM KLINKERFUES	1853–1863	6
CARL BRUHNS	1853–1864	7
GIOVAN B. DONATI	1855–1864	5
F. AUG. T. WINNECKE	1858–1881	13
WILHELM E. TEMPEL	1859–1884	18
LEWIS SWIFT	1862–1890	8
J. COGGIA	1867–1877	7
ALPHONSE BORELLY	1871–1890	7
E. E. BARNARD	1881–1890	13
W. R. BROOKS	1883–1890	12

CONTRIBUTIONS OF RAPHAEL AND OF ALBRECHT DÜRER TO ASTRONOMY.

It may not be known to all that RAPHAEL'S Madonna di Foligno has a special interest to astronomers. It is, I believe, the only painting of any note which commemorates an astronomical event. This picture was painted by RAPHAEL in 1511, and placed in the Church of Ara-Cœli, as a votive offering from SIGISMUND CONTI, secretary to Pope JULIUS II, for his miraculous escape from death by an aerolite. The picture was removed to the Convent of Foligno in 1565 by a niece of CONTI'S, and was carried off by the French in 1792. It was returned in 1815 and is now in the Vatican. Such is a brief sketch of the wanderings of this exquisite painting. Its purely astronomical interest consists in the portrayal of the fall of the aerolite itself, which occupies the centre of the picture. The

drawing must have been made by RAPHAEL from the personal account of CONTI (who was living in 1512), and, therefore, it has even a certain scientific value.

It does not seem to be superfluous to call attention to this item of history, which lends a slight additional interest to one of the world's great pictures. I have presented a good photograph of this painting to the Astronomical Society's library.

The contribution of ALBRECHT DURER to astronomy is even more pronounced and permanent, though it is unknown, I believe, to all of his biographers.

HIPPARCHUS (B. C. 127) and PTOLEMY (A. D. 136) fixed the positions of stars by celestial latitudes and longitudes, and named the stars so fixed, by describing their situation in some constellation figure. The celestial globes of that day have all disappeared, and we have only a few Arabian copies of them, not more ancient than the XIIIth century, so that we may say that the original constellation figures are entirely lost. The situations of the principal stars in each one of the forty-eight classic constellations are verbally described by PTOLEMY. In LALANDE'S *Bibliographie Astronomique* we find that in A. D. 1515 ALBRECHT DURER published two star maps, one of each hemisphere, engraved on wood; in which the stars of PTOLEMY were laid down by HEINFOGEL, a mathematician of Nuremberg. The stars themselves were connected by constellation-figures, drawn by DÜRER. These constellation-figures of DÜRER, with but few changes, have been copied by BAYER in his *Uranometria* (A. D. 1603); by FLAMSTEED in *Atlas Cœlestis* (1729); by ARGELANDER in *Uranometria Nova* (1843), and by HEIS in *Atlas Cœlestis Novus* (1872), and have thus become classic. It is a matter of congratulation that designs which are destined to be so permanent should have come down to us from the hands of so consummate a master.

E. S. H.

PHOTOGRAPHS OF THE LICK OBSERVATORY.

Knowledge for November, 1889, contains some excellent reproductions of photographs taken at and near the Lick Observatory by Mr. BURNHAM. The frontispiece is a capital view of the eye-end of the great telescope. The work was done by the Direct Photo-Engraving Company of London.

Circulation of the *Publications* of the Lick Observatory.

In November, 1888, a copy of volume I of the *Publications* of the Lick Observatory was sent to a library in Boston. A letter lately received states that during the past year it has been taken out by eighty-seven persons, and that nineteen others are registered to receive it in their turn! If the whole edition is read as faithfully, the work will have been useful. E. S. H.

Accessions to the Library.

Dr. George F. Becker, of the U. S. Geological Survey, has done the Observatory a great service by depositing in its library the following volumes from his private collections:

Crelle: *Journal für die reine und angewandte Mathematik;* Vols. 1 (1826) to 15, inclusive; parts of 16 and 18; Vols. 20 to 68, inclusive. [The Observatory set begins with Vol. 100.]

Gilbert: *Annalen der Physik;* complete, 1799–1824; Vols. 1 to 76, inclusive, with index.

Thomson & Tait: *Handbuch der Theoretischen Physik;* Vol. 1; two parts.

Lagrange: *Œuvres de Lagrange;* [Government edition of 1867]; Vols. I, II.

Laplace: *Œuvres de Laplace;* [Government edition of 1843]; Vols. I, II, III, IV, V, VI, VII (bound in 4.)

These books are to remain on our shelves as a permanent loan, until recalled by their owner. The list is given here in order that members of the Society may know of the existence of these works in one of the libraries of the Pacific Coast. Some of them are also to be found in the University Library, Berkeley. E. S. H.

Probable Return of Lexell's Comet.

The news of a remarkable and extremely important discovery in cometary astronomy, made by Mr. S. C. Chandler—so well known as a mathematician and astronomer—has just been received. Mr. Chandler has just completed a preliminary examination into certain peculiarities of the orbit of the comet discovered in July last by Mr. Brooks, and which is still under observation.

This comet has been found to revolve in an elliptical orbit about the sun in seven years. It has attracted particular attention through

the discovery, at the Lick Observatory, of the remarkable companion comets that attend it in its journey through space.

Before speaking of Mr. CHANDLER's discovery, it will be necessary for us to go back, in time, over one hundred years, to the date of the discovery of LEXELL's comet, in 1770. Upon the computation of the orbit of this comet, LEXELL found it to be revolving about the sun in a period of five and one-half years. This was considered remarkable, for the comet was visible to the naked eye, and, therefore, ought to have been seen at some of its former returns. But it had never been seen before—nor has it indeed, been seen since.

LEXELL found that the *aphelion* of this comet was very close to *Jupiter*, and that it had made a very close approach to that planet in 1767. He also found that, previous to 1767, the comet had moved in an orbit whose *perihelion* was near *Jupiter*, and its distance, therefore, so great that it could not be seen from the earth. At this near approach to *Jupiter* in 1767, the planet's attraction on the comet was three times as great as that of the sun, and the comet, therefore, remained in the vicinity of *Jupiter* for many months, its orbit becoming completely changed, so that when it finally was freed from the overpowering influence of the planet, it was thrown into a much smaller orbit, in which it would make a revolution in five and one-half years. In this small orbit it approached very near the earth, and was visible to the naked eye. At its nearest approach to the earth in 1770, it was less than one and one-half million miles distant. So close was this approach, indeed, that LAPLACE computed that if the comet had had any considerable mass, it would have seriously disturbed the motion of the earth in its orbit, and if the mass had been equal to that of the earth, it would have shortened the length of our year by something like three hours. From the fact that no sensible disturbance was experienced from the proximity of the comet, LAPLACE concluded that its mass was certainly less than the one-three-thousandth part of the mass of the earth, or less than one-fortieth of the mass of our moon. It was, doubtless, vastly smaller than that.

In 1779, the comet made a still closer approach to *Jupiter*, and at that time the attraction of the planet on the comet was over two hundred times as great as that of the sun, and the orbit was again changed, the perihelion distance becoming so great that the comet could not be seen from the earth. BURCKHARDT, who verified LEXELL's calculations, found that before the comet came under the influence of *Jupiter* in 1779, its perihelion distance was probably 5.08, while that of the orbit of 1770 was 0.67, and after the disturbance,

through its proximity to *Jupiter*, in 1779, its perihelion distance probably became 3.33, the distance of the earth from the sun being assumed unity. This body, because of its never having been seen since 1770, has been called the *lost comet*, and it has stood as the most remarkable example that we have of planetary influence in disturbing the motions of comets.

We will now return to Mr. CHANDLER'S investigations. He found that BROOKS' comet must have made a remarkably close approach to *Jupiter* in 1886, and that the attraction of the planet then threw the comet into its present orbit, whatever may have been its path previous to that time. This led him to suspect the identity of this comet with the famous LEXELL comet of 1770, and he, therefore, attacked the problem with renewed interest. He found that, previous to the encounter with *Jupiter* in 1886, the BROOKS' comet was moving in an entirely different orbit from that in which it now moves. The periodic time in this former orbit was twenty-seven years, and its aphelion lay outside of *Saturn's* orbit and the perihelion where the present aphelion is.

Mr. CHANDLER, in speaking of the motion of the comet before the disturbance of 1886, says: "Several months before reaching its perihelion, it passed, near the beginning of 1886, into the sphere of *Jupiter's* attraction, and was deflected into a hyperbolic path about the planet, remaining for more than eight months under its control—the disturbing action of the sun during most of that interval being insignificant. The eccentricity of the hyperbola was but slightly in excess of unity, so that the comet narrowly escaped being drawn into a closed orbit as a satellite of *Jupiter*. A slight diminution of the initial velocity relatively to *Jupiter* would have thrown it into an elliptic orbit about the planet."

Mr. CHANDLER also says that, at the close approach to *Jupiter* in 1886, the comet passed a little outside of the orbit of the third satellite, and that it is not impossible that the unequal attraction of *Jupiter* and his satellite system may have caused a disruption of the cometary matter such as would produce the companions that have been discovered attending it, and that these small bodies may owe their existence to the opposing attractions of *Jupiter* and his satellites, in 1886.

What have been the changes that this comet has undergone since 1770 through the repeated disturbances by *Jupiter* it is not possible to tell at present. However, the comet is now, at least, free from the disturbing action of that planet; but this will not continue indefi-

nitely, as it will again encounter *Jupiter* in 1921, under nearly the same conditions as in 1886, and its orbit will again suffer a complete change, the comet, perhaps, once more being thrown into an orbit whose perihelion distance will be so great that it will again be lost to observers, with, perhaps, as long a period of invisibility as it has suffered since 1770, to reappear again some time in the future, through the attractions of *Jupiter*, if, indeed, it can maintain its integrity as a single body under the enormous stresses to which it has been, and may again be, subjected. However this may be, there is very little doubt that Mr. CHANDLER has been the first to point out one of the most remarkable of all cometary histories, and that his discovery is of the first importance. E. E. BARNARD.

MT. HAMILTON, December 5, 1889.

OCCULTATIONS OF STARS AT THE DARK LIMB OF THE MOON, OBSERVED WITH THE TWELVE-INCH EQUATORIAL.

BY E. E. BARNARD.

1889.	L. O. M. T.	STAR.	R. A.	DEC.	REMARKS.
	h. m. s.		h. m. s.	° ′	
Oct. 28	6 30 10.4	B. A. C. 6304.	18 24 23	− 24 13	Good. Instantaneous.
" 28	6 42 09.4	Anon. 9m.....	18 24 43	− 24 09	Good.
" 28	6 46 39.6	W. M. Z. 170.	18 24 55	− 24 13	Good. Instantaneous.
" 28	6 53 22.6	24 Sagittarii* .	18 25 02	− 24 08	Good. Instantaneous.
" 28	7 10 27.8	25 " ..	18 25 41	− 24 20	Good. Instantaneous.
" 30	6 58 23.7	S D. − 22°.5485	20 29 10	− 22 20	Faded slightly 1s before disappearing; then instantly disappeared.
" 30	7 07 36.7	S D. − 22°.5489	20 30 17	− 22 15	Star faint.
" 30	8 16 55.4	S D. − 22°.5498	20 32 05	− 22 08	No remarks.
" 30	8 18 18.2	S D. − 22°.5495	20 31 51	− 22 05	No remarks.
Nov. 25	6 26 19.7	Y. 8364......	19 06 43	− 24 25	Good. Sudden.
" 25	6 39 58.3	W. T. Z. 57 ..	19 07 07	− 24 20	Good. Sudden.
Dec. 29	6 07 52.9	DM. + 2°.205	1 17 35	+ 2 17	Good. Instantaneous.
" 29	6 12 47.9	DM. + 2°.207	1 18 12	+ 2 12	Good. Sudden

* The reappearance of this star was at 7h. 57m. 19s.6; late 1s. or 2s.; limb boiling; star faint. Cloudy weather has interfered with the observations.

NOTE.—The above observations, together with those at the new moons of August and September (see *Publ.* A. S. P., vol. 1, p. 70), have been made here, in the hope that they may be useful to the officers of the U. S. Coast and Geodetic Survey now engaged in determination of longitudes in Alaska. E. S. H.

Efficiency of the Great Equatorial.

The following extract from a paper by Mr. Keeler summarizes the opinions of the astronomers of the Lick Observatory upon the performance of the Great Telescope, and may be of general interest:

* * * * "As the large telescope has now been sufficiently long in use for a thorough test of its various qualities, it may be worth while to give a brief summary of the different kinds of work in which it has proved to be effective.

"*Separation and measurement of close double stars*, as attested by the long list of new doubles, and micrometer measurements of these and of difficult pairs already known, published by Mr. Burnham.*

"*Detection of very faint stars.* Professor Holden and Mr. Schaeberle have observed six stars within the dark interior space of the ring nebula in *Lyra*, besides the central one (No. 14 of Lassell's drawing), and five more within the nebulosity,† and of all these, only the central one was previously known. An example of a double star with extremely minute components, discovered with this telescope, is the pair preceding the trapezium in the nebula of *Orion*.‡ It was found by Mr. Barnard; and Mr. Burnham, who measured it, considers it the most difficult pair with which he is acquainted in the whole heavens.

"In this connection may also be mentioned the observations of the satellites of *Mars*,§ made here during the opposition of 1888 When *Mars* was in opposition the satellites were easy objects, being plainly visible without the aid of an occulting bar to hide the planet, and they were seen as late as July 18th, when their brightness was only 0.12 of that at the time of their discovery in 1877.

"*Observations of the structure of nebulæ.* The *Lyra* nebula has already been mentioned under the preceding division, but only in relation to the minute stars which appear in it. The structure of the nebula itself was better seen by Professor Holden with this instrument than with any other that he had used. He says: 'One's first idea is not so much that the aspect is unfamiliar as that it is distinctly different; that its simple structure has suddenly become com-

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* *Astronomische Nachrichten*, (Nos. 2929 and 2930).

† *Monthly Notices*, R. A. S. (Vol. XLVIII, No. 383).

‡ *Monthly Notices*, R. A. S. (Vol. XLIX, No. 6).

§ *Astronomical Journal*, (No. 178).

plex; and, finally, that the task of depicting it completely is practically impossible by the ordinary methods".* The observations which show the probable existence of helical forms in the nebulæ† should also be mentioned.

"*Observations of comets.* The companions of BROOKS' comet have been observed and measured during the past few months by Mr. BARNARD, who finds a considerable advantage in the thirty-six-inch over the twelve-inch refractor.‡ With the latter instrument the faint companions, called by Mr. BARNARD *D* and *E*, were at all times invisible, although for blackness of field and excellence of definition the twelve-inch telescope is unsurpassed. They have not been seen elsewhere.

"*Definition of the surface features of a planet.* The views of *Jupiter* obtained here during the past opposition have sufficiently proved to all the observers that the large telescope is as suitable for the observation of planetary details as for the other classes of work above given. The extremely fine division discovered by the writer, in the outer ring of *Saturn*, outside of the ENCKE shading,§ has been seen by all the observers here on numerous occasions, but, so far as I am aware, it has been seen at no other place. Finally, I may refer to observations by Professor HOLDEN, not yet published, on details seen in specially interesting parts of the lunar surface.

"These different classes of astronomical work essentially cover the field of visual observation, and in all the thirty-six-inch refractor has shown its capability of yielding the best results." J. E. K.

THE COMPANION TO THE *OBSERVATORY*.

The companion to the *Observatory*, for 1890, has just been issued, and it may be obtained through B. WESTERMANN & Co. (Box 2306, New York City), for 1*s.* 6*d.* It is indispensable to amateur observers, and quite takes the place of the *Nautical Almanac* for most work. It contains ephemerides of the sun, moon, planets and satellites; a list of the principal meteor showers of the year; a list of occultations (for Greenwich); together with full particulars regarding variable and double stars. E. S. H.

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* *Monthly Notices* of the R. A. S. (Vol. XLVIII, No. 9, p. 385).

† *Publications* of the Astronomical Society of the Pacific, (No. 3), and *Himmel und Erde*, (October, 1889).

‡ *Astronomische Nachrichten*, (No. 2919).

§ *Sidereal Messenger*, (No. 62); *Astronomical Journal*, (No. 190); *Ciel et Terre*, (2e serie, t. V., 1889).

Orbit and Mass of the Variable Star *Algol* (*β Persei*).

On the 28th of November a very important discovery was communicated to the Academy of Sciences of Berlin by Professor H. C. Vogel, ~~Director,~~ and Dr. Scheiner, Astronomer of the Astrophysikalisches Observatorium of Potsdam. ~~I condense~~ from the *Sitzungsberichte* of the Academy, 1889, (page 1045), the following :—

"Three photographic negatives of the spectrum of *Algol* taken during the winter of 1888-9 showed that before a minimum *Algol* was moving away from the sun, and after a minimum it was moving towards it. Three new exposures of November, 1889, confirm this result. The observations taken together afford a very strong support to the theory that the cause of the variations in the light of *Algol* is to be found in the eclipses of this star by a dark (invisible) satellite revolving about it. The phenomena can be explained by assuming the following particulars of the dimensions of the two bodies :—

" Diameter of *Algol*	= 230,000	geographical miles.
" Diameter of the invisible satellite	= 180,000	" "
" Distance between their centres .	= 700,000	" "
" Satellite's velocity in orbit . .	= 12.0	" "
" Mass of *Algol*	= $\frac{4}{9}$	of the Sun's mass.
" Mass of the satellite	= $\frac{2}{9}$	" " "

" Motion of both bodies in the line of sight (toward the Sun) 0.5 geographical miles."

E. S. H.

Programme for Meridian Observations of Stars.

When the Repsold meridian circle was ordered, it was designed to use it in determination of the absolute positions of the fundamental stars. Experiments during 1888 and 1889 showed Professor Schaeberle (in charge of the circle) and myself that observations during the daytime were not at all comparable in precision with night observations. It is very rare to find the images in the daytime steady enough to deserve weight 2 (5 = perfectly steady, 1 extremely unsteady), while there are very many nights of weight 4 and weight 5 during the fair season (May to November). The Sun, *Mercury* and *Venus* were often observed at transit during 1889, and the images were always found to be of weight 1, or less. For this reason we reluctantly decided to abandon the plan of referring star places in Right Ascension to the Sun, either directly or through *Mercury* and *Venus*.

All our R. A. observations must then be differential.

The work next in importance seemed to be the observation of all the stars of the English, the French and the American Nautical Almanacs which are visible at Mount Hamilton and which are *not* included in the star-list of the *Berliner Jahrbuch*. There are 127 such stars. If each were referred to the *B. J.* system, we should be far on the way towards making all meridian observations in the northern hemisphere homogeneous, and the extension of the *B. J.* system to the southern hemisphere would be much facilitated. Accordingly a plan was prepared for doing this work and was submitted to Professor AUWERS, who was kind enough to give us the benefit of his counsel. The programme adopted for this part of the work is, in brief, as follows:

The only *B. J.* stars observed will be the nine polars (U. C. and L. C.) and ninety-six stars of the *B. J.* between $+15°$ and $-10°$, together with three other stars slightly beyond these limits. The ninety-nine clock stars are as follows:—

3	47	91	120	151	449	216	266	309
339	53	97	123	432	179	222	269	519
342	56	100	124	434	183	227	495	522
15	550*	102	128	160	186	597*	274	317
21	67	382	131	438	191	233	277	320
349	366	386	134	165	196	237	283	326
29	74	108	138	167	197	241	287	329
35	75	392	141	170	463	245	290	330
37	78	114*	572	172	200	250	297	534
39	84	118	423	174	468*	254	304	333
46	87	569	146	176	212	257	307	336

By this programme the determination of systematic errors is made easy. Each of the ninety-nine clock stars will be observed at least

3 nights direct clamp west.
3 " " " east.
3 " reflected " west.
3 " " " east.

No other stars, except these and the four close circumpolars, will be

* *The four stars 550, 114, 468, 597 are just outside the zone* $+15°$ *to* $-10°$.

regularly observed reflected. Each of the 127 stars from the various Almanacs (and not in the *B. J.*) will be observed at least

6 nights direct clamp west.
6 " " " east.

The declination will be referred to the nadir.

Refraction Stars.

Professor SCHAEBERLE and myself have selected two lists of stars for the determination of the refraction; the northern list contains ninety-three stars north of Z. D. 42° and the southern list contains one hundred and ten stars south of Z. D. 40° as follows:

NORTHERN REFRACTION STARS.
(FROM THE *B. J.*)

Nos.	Nos.	Nos.	Nos.	Nos.	Nos.
169 L. C.	226 L. C.	291 L. C.	5 L. C.	369 L. C.	508
171 L. C.	477 L. C.	504 L. C.	340 L. C.	371 L. C.	415 L. C.
447 L. C.	235 L. C.	508 L. C.	344 L. C.	235	137 L. C.
344	236 L. C.	306 L. C.	19 L. C.	373 L. C.	418 L. C.
19	242 L. C.	137	20 L. C.	92 L. C.	143 L. C.
178 L. C.	484 L. C.	308 L. C.	347 L. C.	379 L. C.	425 L. C.
453 L. C.	485 L. C.	515 L. C.	26 L. C.	388 L. C.	150 L. C.
455 L. C.	256 L. C.	520 L. C.	350 L. C.	490	428 L. C.
184 L. C.	490 L. C.	521 L. C.	459	391 L. C.	154 L. C.
459 L. C.	111	425	38 L. C.	111 L. C.	436 L. C.
462 L. C.	265 L. C.	325 L. C.	43 L. C.	397 L. C.	334
198 L. C.	271 L. C.	529 L. C.	360 L. C.	116 L. C.	439 L. C.
467 L. C.	497 L. C.	530 L. C.	361 L. C.	497	440 L. C.
470 L. C.	284 L. C.	533 L. C.	364 L. C.	284	. . .
220 L. C.	282 L. C.	537 L. C.	217	406 L. C.	.
68	502 L. C.	168	68 L. C.	125 L. C.	. . . .

Southern Refraction Stars.

STAR.	R. A. 1890. H.	R. A. 1890. M.
ε Phœnix	0	04
κ^1 Sculptor	0	05
ι "	0	16
α Phœnix	0	21
β Cetus	0	38
α Sculptor	0	53
β Phœnix	1	01
γ "	1	24
ε Sculptor	1	40
δ Cetus	1	46
μ Fornax	2	08
χ Eridanus	2	23
π Cetus	2	39
β Fornax	2	44
12 Eridanus	3	07
ε "	3	15
y "	3	33
γ "	3	53
o^1 "	4	06
x "	4	14
v^1 "	4	28
α Cælum	4	37
Ll. 9542	4	57
η Pictor	5	02
α Lepus	5	28
α Columba	5	36
κ Orion	5	42
ξ Canis Major	6	16
ξ^2 Canis Major	6	30
ν Puppis	6	34
α Canis Major	6	40
κ "	6	45
ε "	6	53
π Puppis	7	13
25 Monoceros	7	32
f Puppis	7	33
l "	7	38
ι Navis	8	03
γ Argo	8	06
Br. 1197	8	20
α Pyxis	8	39
λ Vela	9	04
λ Pyxis	9	18
α Hydra	9	22
ψ Vela	9	26
6 Sextans	9	46
λ Hydra	10	05
q Vela	10	10
α Antlia	10	22
p Vela	10	33
δ Crater	11	14
ξ Hydra	11	28
Centaurus	11	41
β Hydra	11	47
ε Corvus	12	05
δ "	12	24

	H.	M.		H.	M.
Lac. 5225	12	31	ε Sagittarius	18	17
γ Centaurus	12	35	ξ Telescopium	18	20
ξ_2 "	13	00	σ Sagittarius	18	48
θ Virgo	13	04	ζ "	18	55
γ Hydra	13	13	λ Aquila	19	00
ι Centaurus	13	14	α Sagittarius	19	16
i "	13	38	h "	19	30
μ "	13	43	c "	19	55
π Hydra	13	59	α^2 Capricornus	20	12
θ Centaurus	14	00	κ Sagittarius	20	15
κ Virgo	14	07	ν Capricornus	20	34
κ Centaurus	14	52	ω "	20	44
γ Scorpius	14	58	ζ Microscopium	20	56
γ Libra	15	29	ν Aquarius	21	04
ψ^1 Lupus	15	33	γ Capricornus	21	34
χ "	15	43	ι Piscis Austrinus	21	38
δ Scorpius	15	54	γ Grus	21	47
γ_2 Norma	16	12	η Piscis Austrinus	21	53
α Scorpius	16	23	α Grus	22	01
τ "	16	29	θ Aquarius	22	11
ζ Ophiuchus	16	31	δ Grus	22	23
ε Scorpius	16	43	ε Piscis Austrinus	22	34
θ Ophiuchus	17	15	α "	22	52
ζ Scorpius	17	31	c^2 Aquarius	23	04
κ "	17	35	β Sculptor	23	27
γ Sagittarius	17	59	ε Phœnix	23	29
μ Sagittarius	18	07	δ Sculptor	23	43

The declinations (only) of these stars will be observed as follows: Each star, at least

3 nights direct clamp west.
3 " " " east.

Miscellaneous Stars.

A list of miscellaneous stars will be observed, each star twice. The Observatory will be glad to place any comparison stars needing determination on this list, and to observe and publish in due time. We cannot, however, undertake to make and publish such observations very promptly, as the stars of the other list take precedence, and as there is only one observer for the meridian circle.

The latitude of the Observatory will be determined from the four circumpolars, and also by TALCOTT's method and by prime vertical transits.

A determination of the telegraphic longitude has just been published by the U. S. Coast and Geodetic Survey (*Bulletin* No. 13, 1889). The longitude is $8^h\ 06^m\ 34^s.81 \pm 0^s.1$.

All important stars will be observed (both direct and reflex) through wire screens, so as to reduce their magnitudes to a magnitude between 4 and 6. A reversing prism will be used for stars and nadirs as necessary. At least four nadirs per observing-night will be taken, as well as four determinations of level over mercury, four by the hanging level, one collimation, and one flexure for the present, at least. The division errors of the fixed circle will be determined and the declinations will also be read on the movable circle which is changed 1° every day. Thus the declination of every star observed twelve times should depend on forty-eight division lines of the movable circle and on four lines of the fixed circle.

A *mire* eighty feet distant is read at short intervals. Observations already made and reduced show the excellence of the circle as a whole. The precision of the positions has been materially increased by detaching the clamp-arm from the piers and using the instrument hanging freely in the Y's, as suggested by Professor SCHAEBERLE.

Experiments with the photographic lens of the great telescope will be undertaken to see if differences of declination, etc., can be carried with advantage from plate to plate between pairs of standard stars.

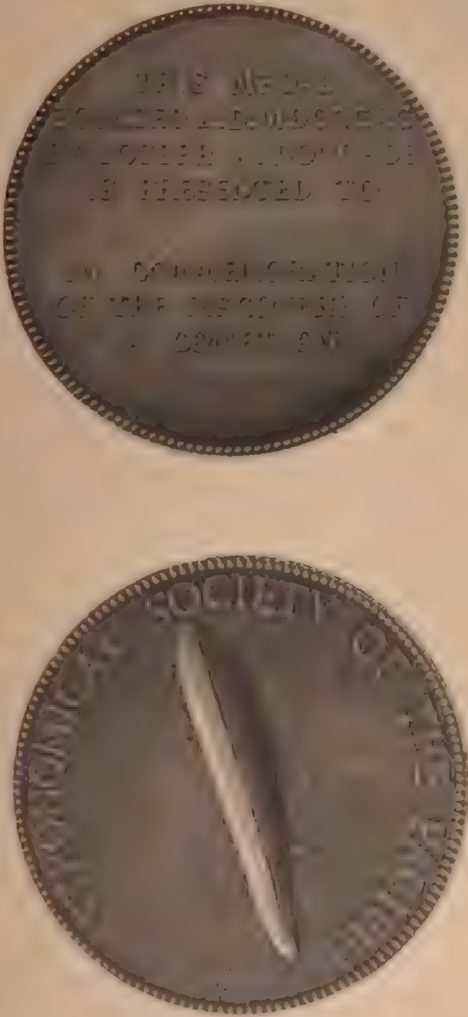
E. S. H.

SOLAR ECLIPSE OF DECEMBER 21, 1889.

The meagre accounts so far received indicate that the African expeditions have failed, on account of cloudy weather. The Lick Observatory party was successful. No account has been received from the other South American parties.

E. S. H.

January 16, 1890.



IS PRESENTED TO
SOCIETY OF THE

Minutes of a Special Meeting of the Board of Directors, held at 408 California Street (after due notice), on December 12, 1889.

Vice-President Pierson in the Chair. A quorum was present.

On motion of E. J. Molera, duly seconded, the following resolutions were unanimously adopted:—

Resolved, That this Society hereby accepts from Alexander Montgomery, Esq., his generous gift of twenty-five hundred dollars, and that William M. Pierson, its First Vice-President, and Charles Burckhalter, its Secretary, be authorized and empowered to execute in duplicate on behalf of this Society, and to attach thereto its corporate seal, the following acceptance of said gift, and to deliver a duplicate original thereof to said Alexander Montgomery.

Resolved, That upon the receipt of said twenty-five hundred dollars the same be deposited, for the present, in equal proportions in the San Francisco Savings Union and the German Savings and Loan Society, until such time as this Board can consider the best means of investing the same.

Resolved, That Edward S. Holden, the President of this Society, be and he is authorized to return to Mr. Montgomery the thanks of this Society for his munificent gift in aid of the Science of Astronomy.

The Alexander Montgomery Fund of the Astronomical Society of the Pacific.

Alexander Montgomery, of the City and County of San Francisco, State of California, hereby gives to the Astronomical Society of the Pacific (a corporation) the sum of twenty-five hundred dollars, gold coin of the United States. The Board of Directors of said Society may determine by the consent, in writing, of at least three-fourths of all its members, whether such fund shall be employed in the procuring of suitable dies, the investment of the remainder thereof in a safe manner, and the striking annually from said dies of a Gold Medal to be awarded by said Society for services to Astronomy; or whether such fund shall be employed by said Society in the purchase of an Astronomical Library for said Society; or whether said fund shall be divided, and if so, how divided, and employed for both said purposes. The decision of said three-fourths of said Directors as to how said fund shall be employed shall be final and unalterable.

In case said fund, or any part thereof, shall be, as aforesaid, applied to the purposes of a medal, the rules for its award shall be adopted by the consent in writing of at least three-fourths of all the Directors of said Society, and said medal shall be forever known as the "Alexander Montgomery Medal" of said Society.

In case said fund, or any part thereof, shall be, as aforesaid, applied to the purchase of an Astronomical Library for said Society, the said library shall be forever known as the "Alexander Montgomery Library" of said Society.

The Astronomical Society of the Pacific hereby accepts said gift under the conditions aforesaid.

In token of the said donation and of its acceptance, and of the mutual agreement of the said donor and donee as to the conditions of the said gift, and that the same may be a matter of perpetual record, the said Alexander Montgomery has hereto set his hand and seal, and the said Astronomical Society of the Pacific has caused William M. Pierson, its First Vice-President, and Charles Burckhalter, its Secretary, thereto duly authorized by its Board of Directors, to hereto set its corporate name and affix its corporate seal, this twelfth (12) day of December, A. D. 1889, in duplicate.

(Signed) Alexander Montgomery. [seal.]

The Astronomical Society of the Pacific,
(Signed) By Wm. M. Pierson,
Vice-President.

The Astronomical Society of the Pacific,
(Signed) By Chas. Burckhalter,
Secretary.

Adjourned.

Minutes of the Meeting of the Board of Directors, held in the Society's Rooms, 408 California Street, January 25, 1890.

The President being unavoidably absent, Vice-President PIERSON presided.

A quorum was present.

The minutes of the last meeting were read and approved.

MATEO CLARK, of London, and ADOLPH SUTRO, of San Francisco, were elected to life membership, subject to the approval of the Society.

The following resolution was unanimously adopted:

Resolved, That the following disposition of the ALEXANDER MONTGOMERY FUND, is approved and ordered to be carried out:

THE ASTRONOMICAL SOCIETY OF THE PACIFIC.

We, the undersigned, composing three-fourths in number of the Board of Directors of the Astronomical Society of the Pacific, hereby exercise the discretion conferred on us by the terms of the gift of twenty-five hundred dollars made to said Society by ALEXANDER MONTGOMERY, Esq., on December 12, 1889, and hereby elect that said fund of twenty-five hundred dollars shall be employed as follows:

One thousand dollars of the principal thereof is hereby set apart to be used in the purchase of a library for said Society, to be composed of books, maps and charts pertaining to the science of Astronomy.

Fifteen hundred dollars thereof shall be safely invested in such manner as the Board of Directors shall determine, and the revenue derived therefrom, or so much thereof as may from time to time be by said Board deemed judicious, shall be used in adding to and preserving said library.

Said library when purchased shall be forever known as the ALEXANDER MONTGOMERY LIBRARY of the Society, and said fund shall be forever known as the ALEXANDER MONTGOMERY LIBRARY FUND of the said Society.

In Witness Whereof, we have hereto set our hands this 13th day of January, A. D. 1890.

WILLIAM ALVORD,	C. MITCHELL GRANT,	E. J. MOLERA,
C. BURCKHALTER,	E. S. HOLDEN,	WM. M. PIERSON,
W. C. GIBBS,	W. H. LOWDEN,	F. SOULÉ.

It was *Resolved*, That complete volumes of the Publications of the Society for past years be furnished to members for one dollar per volume, so far as the stock on hand is sufficient.

The following amended By-Laws were proposed, and approved by the members present:

By-Laws of the Astronomical Society of the Pacific.

ARTICLE I.

This Society shall be styled the ASTRONOMICAL SOCIETY OF THE PACIFIC. Its object shall be to advance the Science of Astronomy, and to diffuse information concerning it.

ARTICLE II.

This Society shall consist of Active, Life, Corresponding and Honorary members, to be elected by the Board of Directors.

1. Active members shall consist of persons who shall have been elected to membership and shall have paid their dues as hereinafter provided.

2. Life members shall consist of persons who shall have been elected to life membership and shall have paid $50 (fifty dollars) to the Treasurer of the Society.

3. Corresponding members shall consist of persons not residing on the Pacific Coast, who shall have been elected as such.

4. Honorary members shall consist of persons specially distinguished for their attainments in Astronomy, not to exceed thirty in number, who shall have been elected as such.

Corresponding and Honorary members shall pay no dues, shall not be eligible to office, shall have no votes, and shall receive the Publications of the Society.

5. A certain number of Observatories, Academies of Science, Astronomical Societies, institutions of learning, etc., not to exceed one hundred, shall be designated by the Board of Directors as Corresponding Institutions, and they shall receive the Publications of this Society in exchange or otherwise.

ARTICLE III.

At each annual election there shall be elected a Board of eleven Directors, and a Committee on Publication, consisting of three members. The officers of this Society shall be a President, three Vice-Presidents, two Secretaries and a Treasurer. The Directors shall organize immediately after their election, and elect from their number the officers of the Society. They may also appoint a Librarian, and such other assistants as may be required. The Directors shall fill by appointment any vacancies which may occur after the annual election.

The Library of the Society shall be kept in San Francisco, and shall be open to the use of all the members.

ARTICLE IV.

The President, or, in his absence, one of the three Vice-Presidents, or, in the absence of both the President and the Vice-Presidents, any member whom the Society may appoint shall preside at the meetings of the Society. It shall be the duty of the President to preserve order, to regulate the proceedings of the meetings, and to have a general supervision of the affairs of the Society. The President is *ex-officio* a member of all Committees of the Board of Directors.

ARTICLE V.

The Secretaries shall keep and have the custody of the records; they shall have the custody of all other property of the Society, excepting the money thereof; they shall give timely notice of the time and place of meetings; they shall keep in books a neat and accurate record of all orders and proceedings of the Society, and properly index them; they shall conduct the correspondence of the Society; they shall preserve and index the originals of all communications addressed to the Society; and keep a copy of all their letters, properly indexed; and they shall prepare for publication an accurate summary of the transactions of the Society at each of its meetings.

ARTICLE VI.

The Treasurer shall receive and deposit in such bank as may be designated by the Directors, to the credit of the Society, all donations and bequests of money and all other sums belonging to the Society. He shall keep an account of all money received and paid by him, and at the annual meetings shall render a particular statement of the same to the Society. Money shall be paid by him only on the written order of the Finance Committee of the Board of Directors. He shall give such bonds as may be required by the Board of Directors.

ARTICLE VII.

Candidates for active or life membership may be proposed by any member of the Society to either of the Secretaries, in writing. A list of such candidates shall be certified to the Board of Directors by the Secretaries at each of their meetings, in writing. A majority (not less than three) of the Directors present at any such meeting shall be required for election.

ARTICLE VIII.

Each active member shall pay an annual subscription of five dollars, due on the first of January of each year, in advance. Each active member shall, on his election, pay into the Treasury of this Society the sum of five dollars, which shall be in lieu of the annual subscription to the first of January following his election, and in lieu of an initiation fee. No one shall be deemed an active member, or receive a diploma, until he has signed the register of members, or accepted his election to membership in writing, and paid his dues for the current year. Any member may be released from annual dues by the payment of fifty dollars at one time, and placed on the roll of life members by the vote of the Board of Directors. Any failure on the part of a member to pay his dues within six months after the time the same shall have become payable, shall be considered equivalent to a resignation.

ARTICLE IX.

The annual meeting of this Society shall be held on the last Saturday in March at eight o'clock P. M., at the rooms of the Society in San Francisco; and bi-monthly meetings shall be held for the ordinary transactions and purposes of the Society, as follows:

Meetings shall be held in the Library of the Lick Observatory, Mount Hamilton, at a suitable hour on the last Saturday of May, the second Saturday of July and the second Saturday of September; and meetings shall be held in the rooms of the Society, in San Francisco, at eight o'clock P. M., on the last Saturdays of January, March and November.

A special meeting may be called by the President, or, in his absence or disability, by one of the Vice-Presidents; or, in the absence or disability of both the President and the Vice-Presidents, by the Secretary, on the written requisition of ten active or life members; and the object of such meeting shall be stated in the notice by which it is called.

The annual election shall be held on the day of the annual meeting, between the hours of 8:15 and 9 P. M.

Only active and life members shall be permitted to vote at any meeting of the Society, and no one shall vote who has not paid all his dues for past and current years. There shall be no voting by proxy.

ARTICLE X.

Fifteen active or life members shall be a quorum for the transaction of business.

ARTICLE XI.

No papers or manuscripts shall be published by the Society without the consent of the Directors. Any motion to print an address, or other paper read before the Society, or any other matter belonging to the Society, shall be referred to the Committee on Publication, who shall report to the Directors. The Committee on Publication may make suggestions to the Directors, from time to time, with reference to the publication of such papers as in their judgment should be published by the Society; and this Committee shall have the care, direction and supervision of the publication of all papers which the Directors may authorize to have published.

Members of the Society shall receive all the publications of the Society free of charge.

ARTICLE XII.

This Society may, by a vote of the majority of all its active and life members, become a branch of an American Astronomical Society, should one be formed.

ARTICLE XIII.

It shall be the duty of the Directors, in case any circumstances shall arise likely to endanger the harmony, welfare or good order of the Society, to call a special meeting of the Society; and if, at such meeting, after an examination of the charges, and hearing the accused, who shall have personal notice of such proceedings, it shall be proposed that the offending member or members shall be expelled, a vote by ballot shall be taken, and if two-thirds of the members present vote in favor thereof, the offending member or members shall be expelled.

ARTICLE XIV.

The Directors shall meet half an hour before the stated time of each bi-monthly meeting, and at such other times as they may appoint. The President, or, in his absence, any one of the Vice-Presidents, may call special meetings of the Board of Directors at any time. Notice of the time and place of such meeting shall be given by the Secretaries, by depositing in the post-office at San Francisco a notice of the time and place, addressed to each Director personally, at his last known place of residence, with the postage thereon prepaid, six days before the time of meeting.

ARTICLE XV.

The By-Laws may be amended at any time by a consenting vote of nine members of the Board of Directors at any duly called meeting thereof.

It was *Resolved* to request Messrs. DONOHOE, KELLY & Co. to keep the Comet medal and dies in their bank-vaults, which they have kindly consented to do.*

It was *Resolved*, That the polls be open from 8 to 9 P. M. at the annual meeting on 29th March, 1890, for the election of eleven Directors and a Committee of three on Publication.

A Library Committee was appointed, consisting of Messrs. MOLERA, BURCKHALTER and PIERSON, to take charge of the one thousand dollars to be used for the purchase of books for the library. Mr. BURCKHALTER was appointed Librarian, and the Committee was given power to act in matters pertaining to the purchase and conduct of the library.

The Treasurer presented his bi-monthly report, which was received and filed.

The bills presented by the Secretary and Treasurer were approved and ordered paid.

The Library Committee was requested to consult with the Mercantile Library Association, and to see if an arrangement can be effected by which the books of the Society can be deposited and cared for in the Mercantile Library.

The meeting then adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD JANUARY 25, 1890, IN THE ROOMS OF THE SOCIETY, SAN FRANCISCO.

President HOLDEN, being snow-bound on Mount Hamilton, Vice-President PIERSON took the Chair.

The minutes of the last meeting were read and approved.

The Secretary announced the receipt of seventy-five presents and publications, among which were two large drawings of *Jupiter* by Professor KEELER, made at the Lick Observatory in July, 1889. The thanks of the Society were returned to the donors.

On motion, the following Committees were appointed by the Chair, to report at the annual meeting, March 29th.

A Committee of three—Messrs. STRONG, GITCHELL and GRAY, to audit the accounts of the Treasurer.

A Committee of seven—Messrs. GODDARD, CEBRIAN, CHURCH, LEWITT, RUNYON, ZIEL and TREAT, to nominate eleven Directors and a Committee on Publication of three members, for election at the annual meeting.

The Chair announced the success of the Lick Observatory eclipse party, sent to South America by Colonel C. F. CROCKER.

The following members were then elected (the names of life members, duly elected by the Board of Directors, are marked with a star (*).

W. STEADMAN ALDIS, ...	University College, Auckland, N. Z.
JOSÉ A. Y BONILLA, ...	Plaza del Mercado 22, Zacatecas, Mexico.
Rev. MARTIN S. BRENNAN, . .	3949 Iowa Street, St. Louis, Mo.
A. R. CHURCH, ...	1102 Tenth Street, Oakland.
MATEO CLARK,*	27 Queen's Gate, London, England.
Hon. LEVI K. FULLER, ...	Brattleboro, Vermont.
Prof. M. W. HARRINGTON, . . .	Director of Observatory, Ann Arbor, Mich.
HUGH HOWELL, ...	1413 Brush Street, Oakland, Cal.
Prof. D. KIRKWOOD, LL. D. . .	Arlington Avenue, Riverside, Cal.
Prof. IRA MORE, ...	State Normal School, Los Angeles, Cal.
T. S. PALMER, ...	Dept. of Agriculture, Washington, D. C.
Hon. ADOLPH SUTRO,*	74 Montgomery Block, San Francisco, Cal.
JAMES L. SCOTT, ...	Turnbull, Howie & Co., Shanghai, China.
Hon. ROBERT SHERWOOD, . . .	309 California Street, San Francisco, Cal.
P. V. VEEDER, D. D.	Laurel Hall, San Mateo, Cal.
FREDERICK G. WATTLES, . . .	Box 2433, Denver, Colorado.

* An *excellent photo-lithograph of the* Comet medal is given in the plate facing page 32.

The Secretary reported that the total membership was now 192, twenty-seven being life-members.

A paper "On the Physical Appearance of Jupiter in 1889," was read by Mr. KEELER, and illustrated by numerous drawings. This was followed by an explanation of the method used for the electrical control of the driving-clock of the great telescope of the Lick Observatory.

The Chair announced that the Board of Directors had, with the consent of Mr. MONTGOMERY, determined to use $1000 of the MONTGOMERY FUND for the purchase of a library, to be known as the ALEXANDER MONTGOMERY Library of the Astronomical Society of the Pacific, and to devote the income of the remaining $1500 to preserving and enlarging the library.

The Society then adjourned to meet March 29, 1890, in its rooms in San Francisco.

CHARLES BURCKHALTER, *Secretary.*

ADDENDUM.—SOLAR ECLIPSE OF DECEMBER 21, 1889.

A telegram from the Lick Observatory Eclipse party recites that the following negatives were secured:

4 with 6½-inch CLARK objective;
5 with 6-inch DALLMEYER objective;
4 with 18-inch SCHAEBERLE reflector;
2 with small camera, just after III contact.

Several of these plates were standardized, in order that measures of the photographic brightness of the corona might be made. The corona was similar in general character to that of January, 1889, only "more extended." It would appear from this expression that the coronal extension, first photographed at the California eclipse, has been again photographed in South America. The negatives have not yet reached the Lick Observatory. E. S. H.

MOUNT HAMILTON, January 31, 1890.

OFFICERS OF THE SOCIETY.

EDWARD S. HOLDEN (Lick Observatory),	*President*
WM. M. PIERSON (76 Nevada Block, S. F.),	*Vice-Presidents*
W. H. LOWDEN (213 Sansome Street, S. F.),	
FRANK SOULÉ (Students' Observatory, Berkeley),	
CHAS. BURCKHALTER (Chabot Observatory, Oakland),	*Secretaries*
J. M. SCHAEBERLE (Lick Observatory),	
E. J. MOLERA (850 Van Ness Avenue, S. F.),	*Treasurer*

Board of Directors—Messrs. ALVORD, BOERICKE, BURCKHALTER, GIBBS, GRANT, HOLDEN, LOWDEN, MOLERA, PIERSON, SCHAEBERLE, SOULÉ.

Finance Committee—Messrs. GIBBS, PIERSON, MOLERA.

Committee on Publication—Messrs. DEWEY, TREAT, ZIEL.

Library Committee—Messrs. MOLERA, BURCKHALTER, PIERSON.

Committee on the Comet Medal—Messrs. HOLDEN *(ex-officio)*, SCHAEBERLE, BURCKHALTER.

NOTICE.

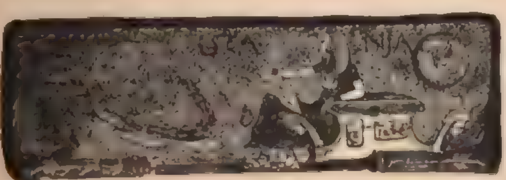
Members are requested to preserve the copies of the Publications of the Society as sent to them. Once each year a title page and index of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume.

It is intended that each member of the Society shall receive a copy of each one of the Publications for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied.

Complete volumes for past years (preceding the calendar year in which any member was elected) will also be supplied to members, so far as the stock in hand is sufficient, on the payment of one dollar to either of the Secretaries.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," at the rooms of the Society, 408 California Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.



PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

No. 7. SAN FRANCISCO, CALIFORNIA, MARCH 29, 1890.

DIE ASTRONOMISCHE GESELLSCHAFT.*

BY DR. HEINRICH KREUTZ, ASTRONOMER IN THE OBSERVATORY OF KIEL.

The *Astronomische Gesellschaft* (Astronomical Society of Germany) was founded at Heidelberg on the 28th of August, 1863, and had its origin mainly in the necessity which was felt for providing for the systematic study and observation of the rapidly increasing number of known asteroids, with an equitable distribution of the labor among those willing to take part in the plan. The first question considered by the society was, therefore, the steps which should be taken toward computing the perturbations of the minor planets, a work on which a number of astronomers had been separately engaged since 1857, and which was now accepted as the first task of the new organization. The results of this co-operation are given in the very first publication of the society,—*Auxiliary Tables for the Computation of Special Perturbations, 1830–1864*,—which appeared in 1865.

The by-laws of the society, which were adopted in 1865, and altered in some essential particulars in 1881, contain the following statements in regard to the objects of the society:

"§ 1. The *Astronomische Gesellschaft* is an association of astronomers and friends of astronomy, having for its object the advancement of this science, particularly in such directions as require systematic co-operation.

"§ 2. It is the special aim of the society to carry on such work as will find continual application in astronomical investigations, and which is best advanced by a combination of forces and adherence to established and consistent principles.

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* It is hoped to present, from time to time, in the Publications of the Astronomical Society of the Pacific, accounts of the organization, history and objects of the Astronomical Societies of the different countries, and, perhaps, of the great observatories of the world. Dr. KREUTZ has kindly consented to prepare the sketch of the German Astronomical Society which is here printed, and it is expected that accounts of other scientific organizations will follow in due course. Some of these papers are already in preparation, through the courtesy of our correspondents.

"In addition to these objects the society seeks by suitable assistance and concentration of forces to further the efforts of those who are engaged in long and important astronomical researches.

"§ 3. The society seeks to attain these ends — (1) By means of scientific meetings; (2) By uniting its working forces, and raising the means for undertaking the more important investigations in astronomy; (3) By the publication of astronomical works; (4) By the formation of collections of literary importance or otherwise of interest."

The scientific meetings mentioned in section 3 have been regularly held every other year since the organization of the society, sometimes in Germany and sometimes in other countries, as, for example, in Leiden, Stockholm, Geneva, and lastly, in 1889, in Brussels. The meetings are opened by reports on the organized work of the society; then follow miscellaneous papers on scientific subjects by the members in attendance; and, finally, the election of directors is held, in accordance with the provisions of the by-laws. The language for all business transactions is German, but it is not prescribed for the papers read before the society nor for the publications.

The other object of the society stated in section 3, to advance the science by uniting working forces and providing the funds for undertaking important astronomical researches, found its first expression in the auxiliary tables for the computation of special perturbations mentioned above; but at the second meeting of the society, at Leipzig, in 1865, a much larger project was considered. This was a plan for organizing a system of meridian circle observations according to a definite programme, which should give accurate positions of all stars down to the ninth magnitude between the limiting declinations of — 2° and + 80°, which are found in the *Bonner Durchmusterung*. This great undertaking, in which two American observatories took part, (Cambridge, Mass., with the zone + 50° to + 55°, and Albany, with the zone + 1° to + 5°), is now nearly completed, and in the near future we may expect the publication of the catalogues which are based on these observations. *

* The Northern Zones were assigned as follows:

From	+ 80° to 75	Observatory of	Kasan.
"	+ 75 to 70	"	Dorpat.
"	+ 70 to 65	"	Christiania.
"	+ 65 to 60	"	Helsingfors.
"	+ 55 to 50	"	Harvard College.
"	+ 50 to 45	"	Bonn.
"	+ 45 to 40		

A continuation of this programme in the southern sky as far as the declination — 23° was decided upon by the society several years ago, and the work was divided among the different observatories, two of which, Washington and Cambridge, are also in America. At some of the places observations have already begun.*

In regard to the minor objects of the society, it may be mentioned that the board of directors provides for the publication of ephemerides of the variable stars, prints the annual reports of observatories and reviews of discoveries of comets and planets, and endeavors to promote co-operation in other questions which do not concern the society so directly, such as the photometric observation of the fixed stars and the definitive determination of cometary orbits.

The official organ of the society is the *Vierteljahrsschrift*, or Quarterly Journal, edited by the two secretaries, at present Professor SCHOENFELD, of Bonn, and Professor SEELIGER, of Munich. The scientific importance of this journal hardly needs to be mentioned, and the reviews of scientific literature, to which, with the affairs of the society, it is mainly devoted, must be regarded as models of their class.

The expenses which the pursuance of the objects of the society involve are covered by the fees of the members, which are fixed at an initiation fee of fifteen marks ($3.75) and an annual contribution of the same amount. Instead of these a single payment of two hundred marks ($50) may be made upon joining.

The third object of the society is the publication of the results of astronomical work. Up to the present time nineteen memoirs on various astronomical subjects in the most diverse branches of the science have been distributed among the members, and before long the catalogues of the extensive zone observations will be added to the number.

From	+ 40° to 35°	Observatory of	Lund.
"	+ 35 to 30	"	Leiden.
"	+ 30 to 25	"	Cambridge (England).
"	+ 25 to 20	"	Berlin.
"	+ 20 to 15	"	Berlin.
"	+ 15 to 10	"	Leipzig.
"	+ 10 to 5	"	Leipzig.
"	+ 5 to 1	"	Albany.
"	+ 1 to −2	"	Nikolaieff.

The Southern Zones have been assigned as follows:

From	− 2° to − 6°	Observatory of	Strassburg.
"	− 6 to − 10	"	Vienna. (Private Observatory).
"	− 10 to − 14	"	Harvard College.
"	− 14 to − 18	"	Washington.
"	− 18 to − 23	"	Algiers.

Besides the zones, a fundamental catalogue of 303 southern stars has been constructed by Professor AUWERS from observations made for the purpose at the Observatories of the Cape of Good Hope, *Madison, Wisconsin, Annapolis*, Maryland, Karlsruhe, Leiden and Strassburg.

The following list will show the importance and diversity of character of the society publications:

PUBLICATIONEN DER *ASTRONOMISCHEN GESELLSCHAFT* (IN QUARTO).

1. *Hülfstafeln zur Berechnung specieller Störungen, 1830–1864.* 1865.
2. LESSER, Dr. OTTO. *Tafeln der Metis.* 1865.
3. WEILER, Dr. A. *Ueber das Problem der drei Korper im allgemeinen und insbesondere in seiner Anwendung auf die Theorie des Mondes.* 1866.
4. HOÜEL, Dr. G. J. *Tables pour la réduction du temps en parties décimales du jour.* 1866.
5. AUWERS, ARTH. *Reduction der Beobachtungen der Fundamentalsterne am Passageninstrument der Sternwarte zu Palermo in den Jahren 1803–1805 und Bestimmung der mittleren Rectascensionen für 1805.* 1866.
6. *Rechtwinklige und Polarcoordinaten des Jupiter . . . . 1770–1830.* 1866.
7. AUWERS, ARTH. *Untersuchungen über veränderliche Eigenbewegungen. Zweiter Theil. Bestimmung der Elemente der Siriusbahn.* 1868.
8. SCHJELLERUP. *Genäherte Oerter der Fixsterne, von welchen in den Astronomischen Nachrichten Band 1–66 selbständige Beobachtungen angeführt sind, für die Epoche 1855.* 1867.
9. LESSER, Dr. OTTO. *Tafeln der Pomona.* 1869.
10. BECKER, Dr. E. *Tafeln der Amphitrite.* 1870.
11. WINNECKE, F. A. T. *Bestimmung der Parallaxe des zweiten Argelander'-schen Sternes.* 1872.
12. WEILER, Dr. A. *Grundzüge einer neuen Störungstheorie und deren Anwendung auf die Theorie des Mondes.* 1872.
13. SPÖRER, Prof. Dr. G. *Beobachtungen der Sonnenflecken zu Anclam, mit 23 Tafeln.* 1874.
14. AUWERS, A. *Fundamental-Catalog für die Zonen-Beobachtungen am nördlichen Himmel.* 1879.
15. HARTWIG, E. *Untersuchungen über die Durchmesser der Planeten Venus und Mars.* 1879.
16. OPPOLZER, Prof. THEOD. v. *Syzygien-Tafeln für den Mond nebst ausführlicher Anweisung zum Gebrauche derselben, mit 3 Tafeln.* 1881.
17. AUWERS, A. *Mittlere Oerter von 83 südlichen Sternen für 1875.0 nebst Untersuchungen über die Relationen zwischen einigen neueren Sterncatalogen.* 1883.
18. ROMBERG, H. *Genäherte Oerter der Fixsterne, von welchen in den Astronomischen Nachrichten Band 67–112 selbständige Beobachtungen angeführt sind, für die Epoche 1855.* 1886.

19. CHARLIER, C. V. L. *Ueber die Anwendung der Sternphotographie zu Helligkeitsmessungen der Sterne.* 1889.

VIERTELJAHRSSCHRIFT DER *ASTRONOMISCHEN GESELLSCHAFT* (IN OCTAVO).

Jahrgang I–XXIV, 1866–1889; also, *Supplementheft zu Jahrgang III:* VON ASTEN, *Neue Hülfstafeln zur Reduction der in der Histoire Céleste Française enthaltenen Beobachtungen.* 1868.

Supplementheft zu Jahrgang IV: Tafeln zur Reduction von Fixsternbeobachtungen für 1726–1750. 1869.

Supplementheft zu Jahrgang XIV: BRUHNS, *Catalog der Bibliothek der Astronomischen Gesellschaft.* 1879.

The fourth object of the society is the collection of articles of literary and scientific interest. The most important of these collections is the library of the society, which, in the course of years, has grown into very considerable dimensions, and is kept in the Observatory at Leipzig.

At the close of the meeting at Brussels in 1889 the society numbered 340 members. Membership is not limited to any nationality, although the German is naturally the prevailing one. A person desiring to join the society must give notice of his wishes to one of the directors. The board of directors gives first a provisional decision upon the admission of the candidate, and later, at the next meeting thereafter, he is finally elected.

The board of directors consists of eight members; a president, two secretaries, a treasurer (who, according to the by-laws, must reside at Leipzig, the seat of the society), and four members without special duties. One of the latter is appointed by the president to act in his place, in case he should be absent. At every regular meeting of the society four of the directors, among them one of the secretaries, retire from office, and their places are filled by a new election. The resigning directors can, however, be re-elected. At the last meeting of the society at Brussels Professor AUWERS, who had been president for many years, expressed his desire to retire from the position, and the board of directors now consists of the following members:

Professor H. GYLDÉN, of Stockholm, President; Professor H. G. VAN DE SANDE BAKHUYZEN, of Leiden, Vice-President; Professor A. AUWERS, of Berlin; M. F. TISSERAND, of Paris; Professor E. WEISS, of Vienna; Professor E. SCHOENFELD, of Bonn, Secretary; Professor H. SEELIGER, of Munich, Secretary; Professor H. BRUNS, of Leipzig, Treasurer.

The next meeting of the society will be held at Munich in August or September, 1891, and a full attendance by our American colleagues would give them a much better idea of the nature and work of the *Astronomiche Gesellschaft* than the above necessarily imperfect sketch, and would serve to bind more closely the ties which unite astronomers on both sides of the ocean.

OBSERVATORY OF KIEL, January 2, 1890.

ON THE ORBIT OF μ^2 *HERCULIS* (Σ 2220).

BY ARMIN O. LEUSCHNER.

[ABSTRACT.]

The duplicity of μ^1 *Herculis* was discovered by Mr. ALVAN CLARK in the year 1856, with an aperture of 7¾ inches. Since then the pair has been regularly observed by the most distinguished observers. In 1879 Dr. W. DOBERCK deduced an orbit of the companion, and arrived at a period of 54.25 years. (*Astr. Nachr.*, 2287.) Recent measures seem to point to a somewhat shorter period. At the suggestion of Mr. S. W. BURNHAM, I have deduced a new orbit, employing therefor the excellent method of Prof. v. GLASENAPP. (*Mon. Not. Royal Astr. Soc.*, March, 1889.) Neglecting a couple of observations made by Messrs. SCHIAPARELLI and BURNHAM in the years 1887 and 1889, I arrived at a period almost identical with that obtained by Dr. DOBERCK. The introduction of the last two observations, however,—the only ones since 1883 accessible to me—renders the representation of the distances by means of the position-angles rather difficult.

The following are Dr. DOBERCK'S and my own elements:

ELEMENTS.	DOBERCK.	LEUSCHNER.
☊	57° 57′	62° 6′.7
i	60° 43′	67° 0′.6
λ	156° 21′	181° 59′.0
e	0.3023	0.2139
a	1″.46	1″.369
T	1877.13	1880.142
P	54.25	45.39

The observations from which the new orbit has been computed were kindly collected by Mr. BURNHAM. The following residuals were obtained from the interpolating curves:

OBSERVER.	EPOCH.	θ_c	s_c	$\theta_o-\theta_c$	s_o-s_c
		°	"	°	"
Dawes	1857.50	63.0	1.75	−3.7	+0.07
Secchi	1857.85	64.0	1.75	+7.7	−0.01
Dawes	1859.70	67.9	1.69	−7.5	+0.36
O. Struve	1860.30	68.7	1.65	−1.0	−0.01
O. Struve	1862.83	75.1	1.44	+3.4	+0.06
Dawes	1864.43	79.6	1.27	−2.0	+0.54
Engelmann	1864.49	80.0	1.27	−12.5	+0.43
Winnecke	1864.76	80.3	1.25	−1.5	+0.51
Knott	1865.43	83.2	1.17	−3.6	+0.67
Dembowski	1865.44	83.4	1.17	−1.4	+0.03
O. Struve	1866.68	89.3	1.02	+0.2	+0.08
O. Struve	1868.50	101.7	0.79	−3.0	+0.09
O. Struve	1871.52	150.0	0.52	+6.8	+0.10
O. Struve	1873.50	188.8	0.59	−3.3	+0.04
Newcomb	1874.49	204.1	0.68	−0.2	+0.07
Gledhill	1874.64	....	0.70	....	−0.30
Schiaparelli	1875.58	215.6	....	−0.4	....
Newcomb	1875.68	216.7	....	+9.2	....
Hall	1875.69	216.7	0.81	+3.9	+0.37
Holden	1875.70	216.7	....	+0.9	....
Hall	1876.59	223.7	0.86	−0.3	−0.14
Dembowski	1876.68	224.4	0.89	−8.4	−0.06
Hall	1877.59	230.1	0.98	+2.7	−0.13
Schiaparelli	1877.59	230.1	0.98	−2.2	−0.18
Dembowski	1877.62	230.2	0.98	−0.3	−0.10
Burnham	1878.48	234.9	1.04	±0.0	+0.01
Hall	1878.50	234.9	1.05	−1.1	−0.17
Burnham	1879.45	239.9	1.08	+2.8	−0.18
Hall	1879.55	241.0	1.12	−1.5	−0.15
Schiaparelli	1880.46	245.8	1.07	−15.6	−0.31

Observer.	Epoch.	θ_c	s_c	$\theta_o - \theta_c$	$s_o - s_c$
		°	″	°	″
Burnham..............	1880.47	245.8	1.07	+0.1	−0.11
Hall.................	1880.70	246.3	1.07	±0.0	+0.01
Burnham..............	1881.41	250.1	1.03	+2.0	−0.11
Hall.................	1881.54	250.6	1.03	−1.5	−0.02
Hall.................	1882.52	256.4	0.96	+2.7	−0.26
Schiaparelli...........	1882.60	257.0	....	+9.8	....
Burnham..............	1883.53	263.0	0.86	−0.9	−0.12
Hall.................	1883.58	263.3	0.85	−1.0	−0.11
Schiaparelli...........	1883.63	263.7	....	+11.1	....
Engelmann...........	1883.96	....	0.81	....	−0.20
Schiaparelli...........	1887.54	317.9	0.49	+0.4	±0.00
Burnham..............	1889.51	358.4	0.57	−0.5	−0.02

BERKELEY, December, 1889.

ON THE SIMILARITY OF CERTAIN ORBITS IN THE ZONE OF ASTEROIDS.

BY DANIEL KIRKWOOD, LL.D.

The occasional separation of comets into two or more fragments is no longer questioned. It may be asked, however, whether phenomena of this nature have been limited to comets, or whether indications of similar divisions may not be traced in the group of asteroids? This question, suggested some time since,* is one of much interest, but data for its discussion are still far from satisfactory. In order to facilitate the comparison of orbits so as to present at one view the most remarkable resemblances, I take a table of asteroidal elements, arranged in the order of their mean distances, and assume small, admissible limits of difference in the values of the distance, eccentricity, inclination, perihelion and node. In this comparison, however, it is to be borne in mind that the difference in longitude of the perihelion, as also in that of the node,

* *The Asteroids* (p. 48).

may have attained considerable magnitude. Adopting, arbitrarily, the following limits of difference,

$$(a - a') < 0.005$$
$$(e - e') < 0.025$$
$$(i - i') < 2^\circ$$
$$(\pi - \pi') < 20^\circ$$
$$(\Omega - \Omega') < 30^\circ$$

I move along the column a till I find two distances differing less than 0.005. Then, following the horizontal line through the corresponding columns, I discover by inspection what other elements fall within the assumed limits. I thus obtain the following cases of remarkable similarity:

	Pairs.		a	e	i	π	Ω
					° ′	° ′	° ′
I	*Vera*	(245)	3.1039	0.1960	5 11	27 13	62 12
	Semele	(86)	3.1015	0.2193	4 47	29 10	87 45
II	*Clotho*	(97)	2.6708	0.2550	11 46	65 32	160 37
	Juno	(3)	2.6683	0.2579	13 1	54 50	170 53
III	*Maia*	(66)	2.6454	0.1750	8 17	48 8	8 17
	Fides	(37)	2.6440	0.1758	8 21	66 26	8 21

Eurynome (79) and *Fortuna* (19) have also a striking resemblance.

In view of the facts here presented the division of primitive masses seems less improbable than the accidental coincidence of so many elements. The cause, of whatever nature, which has separated the tenuous matter of comets may have been operative also in the original condition of the minor planets. The fact that where the inclination, eccentricity, longitude of perihelion and of the node, are most nearly coincident, the orbits are closely contiguous, is best explained by the theory of separation.

While, then, the hypothesis of explosion, as proposed by Olbers, is no longer tenable, the facts of observation indicate the ancient dismemberment of primitive masses in the asteroidal group.

Arlington Avenue, Riverside, Cal., Feb. 10, 1890.

ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, AT THE SECOND ANNUAL MEETING (MARCH 29, 1890).

By EDWARD S. HOLDEN.

It is customary in scientific societies for the retiring President to deliver an address at the end of his term, choosing some subject closely related to the special object of the society's existence. I may claim, perhaps, unusual freedom in conforming to this custom, because I have already delivered such an address "On the Work of an Astronomical Society" at our first annual meeting.* It would be of great interest to review the work of the Society during the past year, and to consider the very useful relations in which we are already established. Perhaps, however, it is too soon for such a detailed review, and I may leave it to my successor, and choose a different topic. It will not be out of place to summarize the statistics of the first year of the Society, in the briefest way. We began our existence very modestly and simply, on the 7th of February, 1889, with a membership of forty, almost all citizens of San José or San Francisco. At this time we have 192 members (27 life, 165 active), and they are scattered from London to Venezuela, from Mexico to British Columbia, and in the United States from Boston and New York to California. Beside this, we regularly send our *Publications* to nearly one hundred observatories, academies of science, libraries and public institutions distributed all over the world, in England, France, Spain, Portugal, Italy, Germany, Austria, Russia, Denmark, Sweden, in Africa, Asia, Australia and the islands of the Pacific, in both North and South America. Whoever contributes a paper to our *Publications* is addressing not only our small audience of California amateur and professional astronomers, but he is speaking directly to the whole world of astronomy and of astronomers. There is no cause to fear such an audience. No one is so well able to estimate the spirit in which any piece of faithful work is done as the professional observer, who knows what infinite pains are necessary to accomplish great tasks —not only what pains, but what native abilities are needed. If we are, as I have said, active, alive, modest, competent, we may be sure that our work will be received and welcomed on account of the spirit in which it is done; and that its amount and lasting value will be generously and not grudgingly weighed. We have already to thank

* *Publications* A. S. P. No. 2.

the courtesy of many distinguished institutions and individuals for the welcome our work has received at their hands. Such a welcome will teach us to hold our ideals high, while, at the same time, we must be willing to take the little steps that are necessary to advance, and not be discouraged if our present progress is not by strides, as we might wish.

Our *Publications* have presented the work of the astronomers and of the students of the Lick Observatory chiefly (as was natural during the first year of our existence). We have, however, a number of other papers promised or on hand from non-members of the Society. I must, however, repeat what I said in my former address, that the amateur members of the Society should fill the first part of our papers. The *Notices from the Lick Observatory* afford a field for presenting the work of our professional members in California, and they seem to have served a useful purpose thus far.

We should not allow this occasion to pass without a grateful acknowledgment of the material contributions which we owe to several of our members, which have already been serviceable to science. The eclipse expedition, sent out at the expense of Colonel CROCKER, has been fully successful, and our knowledge of this eclipse will rest upon the observations of the South American parties alone. The Lick Observatory party has secured fourteen satisfactory photographs, some of them of great importance.

The comet-medal founded by Mr. DONOHOE will promote the discovery and encourage the observation of comets, not only now but always. In my view, the attitude taken by the Society and by the founder of this medal is precisely the right one. We are eager to commemorate each piece of useful work done in this direction, and we desire to recognize the merit of the discoverers of comets; but we are far from thinking that any reward for such labors can be given. The reward is the discovery itself. It was fortunate for the Society that Mr. DONOHOE was able to be in Paris, and to attend personally to the matter of selecting the beautiful designs for this medal, which is a real work of art.

The generous gift of the MONTGOMERY Fund will be used to establish a library for the members of the Society in San Francisco. A solid nucleus for the MONTGOMERY Library will be purchased outright and at once; a portion of the fund will be invested, and the interest applied to increasing our collections. Exchanges with other scientific societies and with observatories will yield us many most valuable and important works, and our thanks are due to the correspondents who have already contributed to the Society Library, and

also to the Smithsonian Institution, which transmits these gifts to us without charge.

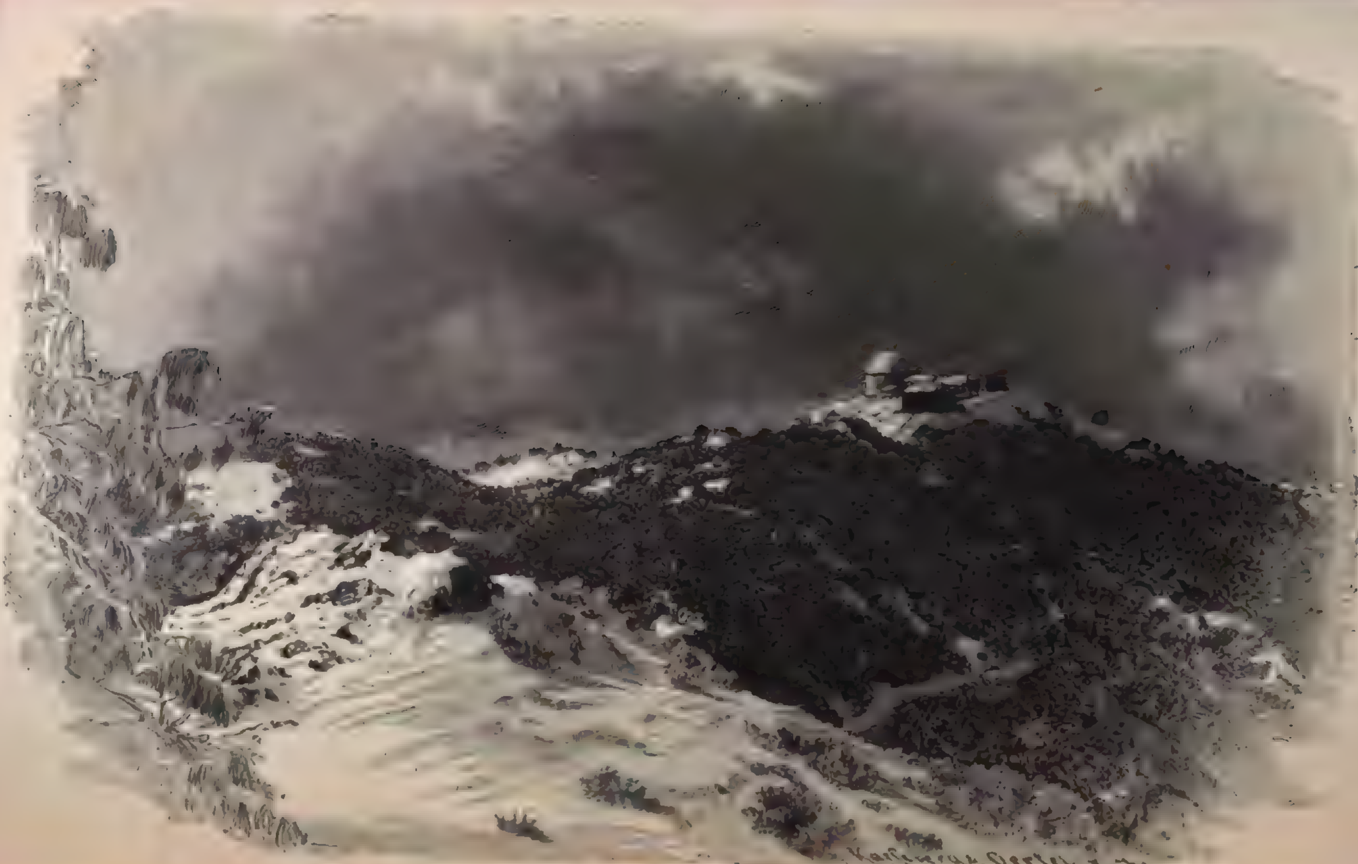
I think that one of the best uses of the Society will be to help to place before the people of our State, directly and indirectly, the purposes for which observatories are founded and the problems which astronomy has now to consider. These are very little understood anywhere, and perhaps less so in California than in any other equally intelligent community. We all understand why our particular development as a community has not, so far, favored the cultivation of this special science; but our very existence and prosperity as a Society is a striking evidence of how readily interest is awakened and of how steadily it is maintained.

The members of the Society already exert a very wide personal influence to increase the general interest in astronomy; and this will grow from year to year. If our members will arrange among themselves to prepare short abstracts of our publications in popular form for printing in the daily newspapers in their vicinity, this influence and our usefulness will be very rapidly extended.

Let me leave the subject of the development of the Society, and address myself to the special topic I have proposed to treat. I wish to give you what may be called the unofficial or personal view of life and work at the Lick Observatory.

We all know the official and impersonal side, and it is, of course, by far the most important one; in a sense, it is the only one. There is the great Observatory, founded by private generosity, and carefully equipped with instruments of the best design. There is the corps of observers, who have already done much with the opportunity afforded them. This is the official view of the institution, and the publications of the astronomers in the various scientific journals are the official vouchers for their work. This is a more or less familiar view of the Observatory, and, as I say, it is the official one. It is like the view which is obtained during a summer visit to Mt. Hamilton, when the landscape is smiling in the sun, and when everything wears its holiday dress. Nothing is more charming than the drive to and fro; nothing seems simpler than the organization of effort and work; nothing seems (and nothing is) so delightful as a life of devotion to one's chosen profession among such beautiful and grand surroundings, as one of a company of fellow-workers.

There is, however, another side to the life at Mt. Hamilton, which I may call its personal aspect. It is not in opposition to the



Lick Observatory in Winter

first view, but rather its complement. No one of the astronomers is less attached to his science and to his work for any incidental hardships there may be in this life; in fact, you cannot know how sincerely and devotedly he is attached until you yourself know both sides of his existence. I have thought that I might give you some idea of this other half of our lives without running the risk of dealing with too familiar and intimate matters. If I can do so, you will conceive of the whole institution as it really is, and not as it seems to be; and you will have some idea of the total activity, and not simply of the astronomical effort. Before the least scientific work can be done, life must somehow be organized. If the shutters of the great dome are frozen tight together, the great telescope cannot be used. If there is no wood to burn in the office-stoves, no computations can be made, no matter how enthusiastic may be the computer. If the chimneys of the Observatory will not draw, it is beyond any man's power to work at his desk, be he never so devoted. These matters must be attended to somehow. The energy that is left over is available for the astronomical work.

The life of an isolated and highly specialized community ought to have something interesting quite in itself; and I wish, if I can, to give you some idea of our life as a whole. If I succeed in this, I shall have written a chapter in the history of the Lick Observatory which is certainly worth writing, although it has no place among official records, and although it assumes a friendly and interested audience—which, I am sure, I may count on. Allow me, then, to begin by showing you some exquisite winter views of the Observatory from photographs by Mr. BURNHAM and Mr. BARNARD.

The wood cuts which accompany this paper have been kindly presented by the editors of *Himmel und Erde*, the *Universal Review*, *Engineering*, and by Messrs. WARNER & SWASEY, to whom our thanks are due. They will serve to recall the various aspects of the landscape to those who have once seen it. I regret that it is impossible to show some of the most characteristically beautiful winter effects, even by the photograph. One has to live at Mt. Hamilton to see them. They cannot be photographed. Sometimes for days and days we are under a huge hemispherical cup of cloud whose rim is lifted up a few degrees all around the horizon. Outside of this envelope the sun is shining brightly on the snowy tops of Monte Diablo, Loma Prieta, Santa Lucia and on the range of the Sierras from the Yo Semite far southwards along the great valley, and all of

these glorious mountain outlines are in full view. No one who has seen this sight can ever forget it; but there is no way to reproduce it for others.

The photolithograph (from a negative by Mr. BURNHAM) gives a general view of the summit of the mountain on February 21st, 1890, at the end of the severest snow-storm of the season. The drifts near the small dome are ten feet deep, and those near the astronomers' cottages at the foot of the hill are even deeper, so that the quarters present something the appearance of an Eskimo *igloo*.

In order to give some definite notion of a severe winter's weather, let me copy part of the record for November and December, 1889, and January and February, 1890:

METEOROLOGICAL OBSERVATIONS FOR THE MONTHS OF NOVEMBER AND DECEMBER, 1889, AND JANUARY AND FEBRUARY, 1890.

(From November 1st to 15th the weather was mostly clear or fair. The present record commences with the 16th. The mean annual barometer is 25.766 inches.)

DATE.	Mean Daily Barometer.	Rain or Melted Snow.	For 24 hrs. ending at noon. Maximum Velocity of the Wind.	Total Movement of the Wind.	REMARKS.
	Inches.	*Inches.*	*Miles.*	*Miles.*	
Nov. 16, 1889	25.81	. . .	60	159	Clear.
" 17 "	25.77	. . .	50	142	Fog.
" 18 "	25.61	.73	37	542	Rain.
" 19 "	25.80	.91	28	382	Rain.
" 20 "	25.82	1.66	17	259	Rain.
" 21 "	25.87	.15	24	312	Clear.
" 22 "	25.69	.14	30	638	Fog.
" 23 "	25.77	.60	28	282	Cloudy.
" 24 "	25.85	. . .	10	119	Clear.
" 25 "	25.95	. . .	30	285	Clear.
" 26 "	25.81	. . .	33	564	Fair.
" 27 "	25.63	. . .	60	880	Cloudy.
" 28 "	25.58	. . .	60	821	Cloudy.
" 29 "	25.60	.06	50	841	Cloudy.
" 30 "	25.60	.21	33	510	Cloudy.
Sums. . . .	. . .	4.46	. . .	. . .	

General View of the Summit of Mount Hamilton, February [illegible]

Date.	Mean Daily Barometer.	Rain or Melted Snow.	For 24 hrs. ending at noon. Maximum Velocity of the Wind.	Total Movement of the Wind.	Remarks.
	Inches.	*Inches.*	*Miles.*	*Miles.*	
Dec. 1, 1889	25.57	.70	26	772	Rain.
" 2 "	25.71	.34	33	767	Fog.
" 3 "	25.70	.29	30	326	Fog.
" 4 "	25.57	.63	43	756	Rain.
" 5 "	25.52	.53	60	775	Rain.
" 6 "	25.49	1.01	37	561	Rain.
" 7 "	25.71	1.50	50	736	Rain and fog.
" 8 "	25.62	.94	18	290	Rain.
" 9 "	25.82	.21	37	503	Fog.
" 10 "	25.60	.59	50	530	Rain.
" 11 "	25.51	.52	43	705	Rain and fog.
" 12 "	25.56	.04	17	231	Fog.
" 13 "	25.71	.17	14	226	Fog.
" 14 "	25.74	. . .	17	164	Fog.
" 15 "	25.78	. . .	10	167	Clear.
" 16 "	25.77	. . .	43	372	Cloudy.
" 17 "	25.72	.58	24	245	Rain and partly clear.
" 18 "	25.69	.08	43	513	Snow.
" 19 "	25.83	.71	30	459	Rain.
" 20 "	25.79	1.53	60	400	Rain and fog.
" 21 "	25.54	.05	60	. . .	Fog.
" 22 "	25.45	.19	. . .	. . .	Snow.
" 23 "	25.31	.04	. . .	. . .	Snow.
" 24 "	25.41	.58	. . .	. . .	Rain and fog.
" 25 "	25.65	.78	. . .	. . .	Rain and cloudy.
" 26 "	25.71	.06	22	501	Fog.
" 27 "	25.75	.03	20	254	Fair.
" 28 "	25.82	.08	26	287	Fog.
" 29 "	25.95	.35	24	291	Rain and cloudy.
" 30 "	25.74	.10	28	386	Fog.
" 31 "	25.68	.56	33	459	Rain and fog.
Sums. . . .	. . . .	*13.19*	. . .	. . . .	

Date.	Mean Daily Barometer.	Rain or Melted Snow.	For 24 hrs. ending at noon. Maximum Velocity of the Wind.	Total Movement of the Wind.	Remarks.
	Inches.	*Inches.*	*Miles.*	*Miles.*	
Jan. 1, 1890	25.64	. . .	15	269	Fog.
" 2 "	25.50	.60	50	. . .	Rain.
" 3 "	25.35	. . .	. . .	. . .	Snow.
" 4 "	25.39	. . .	. . .	. . .	Snow.
" 5 "	25.57	.11	. . .	. . .	Fog.
" 6 "	25.68	.30	. . .	. . .	Fair.
" 7 "	25.85	.22	. . .	. . .	Clear.
" 8 "	25.82	.14	22	412	Clear.
" 9 "	25.76	. . .	28	253	Cloudy.
" 10 "	25.65	.18	17	202	Clear.
" 11 "	25.82	. . .	22	342	Clear.
" 12 "	25.86	1.29	33	445	Rain.
" 13 "	25.85	.06	. . .	199	Fair.
" 14 "	25.83	. . .	50	436	Clear.
" 15 "	25.66	. . .	60	482	Snow.
" 16 "	25.58	.41	27	509	Snow.
" 17 "	25.54	.69	30	. . .	Snow.
" 18 "	25.67	.07	. . .	. . .	Fog.
" 19 "	25.84	.05	. . .	. . .	Fog.
" 20 "	25.81	.01	. . .	. . .	Fair.
" 21 "	25.64	.01	. . .	. . .	Fair.
" 22 "	25.67	. . .	. . .	. . .	Fog.
" 23 "	25.65	. . .	60	. . .	Rain.
" 24 "	25.59	2.09	62	237	Rain.
" 25 "	25.57	1.10	24	253	Rain.
" 26 "	25.76	.11	. . .	541	Clear.
" 27 "	25.82	. . .	. . .	. . .	Clear.
" 28 "	25.89	. . .	. . .	612	Fair.
" 29 "	25.83	.37	. . .	345	Rain.
" 30 "	25.86	.12	12	145	Cloudy.
" 31 "	25.88	. . .	15	183	Clear.
Sums. . . .	. . .	7.93	. . .	. . .	

VIEW OF ASTRONOMER'S COTTAGE, LICK OBSERVATORY, February 20, 1890.

Date.	Mean Daily Barometer.	Unmelted Snow.	For 24 hrs. ending at noon.		Remarks.
			Maximum Velocity of the Wind.	Total Movement of the Wind.	
	Inches.	*Inches.*	*Miles.*	*Miles.*	
Feb. 1, 1890	25.93	. . .	12	203	Fair.
" 2 "	25.93	. . .	14	257	Fair.
" 3 "	25.93	. . .	13	110	Fair.
" 4 "	25.97	. . .	24	378	Clear.
" 5 "	25.94	. . .	22	349	Fair.
" 6 "	25.90	. . .	19	311	Clear.
" 7 "	25.89	. . .	13	147	Fair.
" 8 "	25.83	. . .	13	100	Clear.
" 9 "	25.83	. . .	33	526	Clear.
" 10 "	25.96	. . .	24	345	Clear.
" 11 "	26.05	. . .	10	112	Clear.
" 12 "	25.87	. . .	43	395	Clear.
" 13 "	25.67	. . .	24	298	Clear.
" 14 "	25.74	. . .	37	541	Fair.
" 15 "	25.59	. . .	70	. . .	Fog.
" 16 "	25.37	1	22	. . .	Fog.
" 17 "	25.41	7	* . . .	. . .	Snow.
" 18 "	25.39	12	. . .	. . .	Snow.
" 19 "	25.49	13	. . .	. . .	Snow.
" 20 "	25.49	14	. . .	. . .	Snow.
" 21 "	25.50	9	. . .	. . .	Snow.
" 22 "	25.72	8	. . .	. . .	Fair.
" 23 "	25.67	. . .	. . .	. . .	Fair.
" 24 "	25.62	. . .	. . .	. . .	Fog.
" 25 "	25.53	2	. . .	. . .	Fog and snow.
" 26 "	25.61	. . .	. . .	. . .	Clear.
" 27 "	25.81	. . .	. . .	. . .	Clear.
" 28 "	25.76	. . .	. . .	. . .	Fair.
Sums . . .	. . .	66	. . .	. . .	

* After this date the anemometer was frozen so that no record was obtained.

The total *snow*-fall was for December, 29 inches; for January, 51 inches, and for February, 66 inches, or *twelve feet* in all. Some of the January snow was on the ground when the February storms began. During five days of February, 1890 (the 16th to 20th), absolutely no communication with the outside world was *possible*. The snow fell in immense quantities, and a fierce *blizzard* was blowing which could not be faced. On the sixth day of our imprisonment three men started together for Smith Creek, and returned the same night, bringing a mail and thirty pounds of much needed provisions, after a journey of fourteen miles, which had taken something like eight or nine hours of very hard work.

To take the Observatory as a whole, we must consider not only the astronomical establishment, with its purely scientific aims, but, rather, the reservation of 1900 acres, with its village, containing a colony of thirty to forty people and eight or nine families. There are ten different sets of quarters occupied at the present time by astronomers, students and workmen.

There is no want which can be felt in the city which is not equally pressing here. But consider how difficult it sometimes is to supply these wants. Take even the case of mere food-supply during our winter storms. There is nothing to be had nearer than San José, twenty-six miles away, and it is necessary to transport everything by the stage.

Frequently the stage has not room for all our parcels, and very frequently has no passengers for the Observatory, and stops at the foot of the mountain. In such a case, we must send our own men and wagon over the fourteen miles of road to the valley of Smith Creek. Very often during the past winter the road has been impassable to wagons (on account of the snow), and all our supplies have been brought in the mail-bag on horseback. Whatever was too large or too heavy for the bag was not brought, and had to be done without. During the one hundred and twelve days from November 15th to March 8th, the stage only came to the Observatory thirty-six times. The difficulties in this matter can be met by a kind of "forehandedness"; but when we come to the strictly scientific side of our necessities, they are more serious. For example, a bit of colored glass is wanted, to moderate the brightness of *Mars*, so that the satellites can be more easily seen. Where is it to be had? There is not so much as a square millimeter of such glass west of the Allegheny mountains.

One of the prisms of our spectroscope is stained and yellow, so that part of the blue end of the spectrum is cut off. It cannot be

THIRTY-SIX-INCH TELESCOPE, LICK OBSERVATORY.
(By the courtesy of *Himmel und Erde*.)

repolished nearer than Pittsburg. If it is sent away, we lose its use for a month or more. San Francisco has everything that is needed for its business life; but, every now and then, our very special needs absolutely cannot be met nearer than New York or Europe. This means delays, and possibly a loss of the work in hand. The want of a particular kind of chimney for our standard photometric lamp (which had to be imported from Europe, finally, after fruitless attempts to buy it or to have it made in America) delayed the appearance of our Eclipse Report from May to October, for example. Another parcel ordered from London in March, was not delivered here till the following December, and so on. The negatives of the Solar Eclipse of December 21st remained at the foot of the mountain from February 16th until March 5th, for lack of some way to bring them up. The Eclipse instruments were delayed in San José for nearly two months before they were finally delivered.

All this experience has developed the resources and ingenuity of our astronomical staff to a very high degree. To take a single example, I may mention the very ingenious and satisfactory electric control to the driving-clock of our great equatorial, which was invented by Mr. KEELER, and made in the Observatory out of the simplest materials.* It has completely taken the place of the elaborate device which preceded it. But, I think, any mechanic would be disposed to smile at the composite nature of the construction. As in this case, so in very many others. If anything has to be done, the first question is, How? And the next, Where? The usual answer is, if we do not do it ourselves it will be finished too late for our use. And the usual result is that the apparatus is made here, as best we may. All great observatories except our own have an instrument-maker attached to the staff, who can even construct a new instrument, if necessary—and we anxiously look forward to the time when such an official can be added to our own force—when it will not be necessary to use ability of high class in doing merely mechanical work. At the end of every two hours of every night the observer must leave his work and wind the huge weight of the driving-clock of the great telescope (600 lbs.; 320 half turns of the handle!) which has run down. From this really severe labor he must return, with steady nerves (if possible) to making delicate micrometer measures—to moving a spider line over little distances like the $\frac{8}{10000}$ths of an inch ($= 0''.1$), till it just bisects the

* See *Publications* Astronomical Society of the Pacific, No. 6.

disc of a planet, a comet, or a star. A very few dollars would supply us with a water-wheel to wind our weight, but the money is not yet available. You have all seen the exquisite negatives and prints made by our two distinguished photographers, Messrs. BURNHAM and BARNARD; but perhaps you have not considered that every particle of this work has been done by these gentlemen in addition to their regular astronomical observations.

If we had (as I hope that we soon may have) a regular photographic assistant, his whole time could be well spent in carrying out the work connected with this subject—in making prints and enlargements, etc., from the negatives taken by the astronomers at night.

The frontispiece to the Lick Observatory Eclipse Report of last January is an interesting example of what must needs be done. The funds allotted to the Observatory did not allow us to illustrate our report. The printing of the text was excellently executed at the State Printing Office in Sacramento. The edition was one thousand copies, and every one of those copies has a beautiful silver print of the corona for a frontispiece. How did it come to be there? Over one thousand five hundred prints were made by Mr. BARNARD, and the one thousand best ones were selected. Each of these thousand prints was separately mounted by him on cardboard, and sent to the printer; and in that way our report was suitably illustrated. The cost was only a few dollars. If it had been more, we should have been obliged to forego the opportunity. The other cuts in the report we owe to the kindness of the Council of the Royal Astronomical Society, who presented us with electrotypes from their own publications.

There are countless instances of the kind which could be cited. The great telescope was designed to have its circles read by means of electric lights; but the Observatory was turned over to the Regents before these were provided. It was legally "completed" at that transfer. Consequently, we cannot read the circles at all at night, and shall not be able to until we are able to save enough money out of our scanty annual appropriation to buy the necessary appliances. Part must be saved this year, and part the next, and so on, till finally *this* want is supplied. The Observatory is only one department of the University, and there are very many pressing calls for money at Berkeley which the Regents must consider. In my opinion, they have allotted for our annual expenses all that can be spared from the University income without injuring the development of the whole institution; but, while we do not ask for more, the sum *is* inadequate. It is but six-tenths of one per cent. of the first cost

THIRTY-SIX-INCH TELESCOPE, LICK OBSERVATORY.

(By the courtesy of Messrs. WARNER & SWASEY.)

of the Observatory. I often think that the foresight, intelligence and industry which is required to use this sum so that our astronomical work may not absolutely come to a standstill, would, if applied in business, produce ten times our present annual income. It is not easy, at first sight, to understand the necessity for constant small changes in apparatus and instruments which, when effected, make the difference between absolutely first-class and merely good results. The idea of those who do not reflect is, here is a telescope; look through it and "discover" something! The real question is to arrange every detail of the apparatus and work, so that one can improve a little on the splendid results obtained by the other great telescopes of the world, directed, as they are, by the most skillful and accomplished observers. It is by attention to relatively small improvements in apparatus, etc., that relatively great advances are made. The difference between the REPSOLD and the DOLLAND heliometers gave to BESSEL the parallax of 61 *Cygni*.

While such changes and expenses must be provided for, there are vast fields of work always open to any astronomer with any powerful instrument; and at the Observatory we are able to point to our past history, and to prove by it that we have not neglected our opportunities. The object of the present paper is to show how these opportunties have to be made first and improved afterwards, under special circumstances of situation and endowment. It would be a most ungracious task to point out the hindrances, if we could not refer to satisfactory achievement obtained in spite of them.

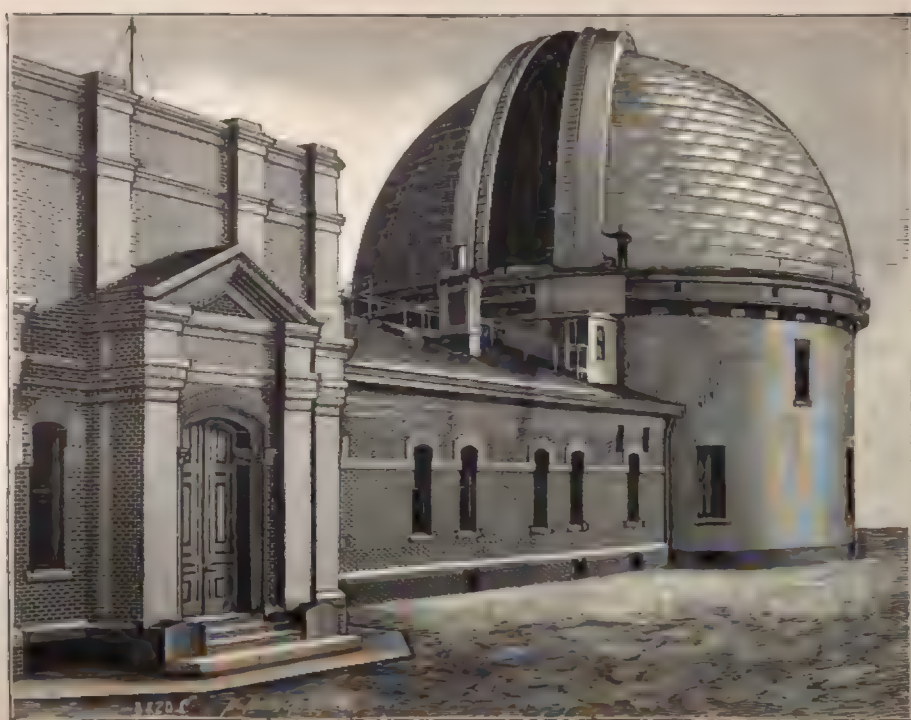
I think there is hardly any department in which we feel so cramped for funds as in that of the library. It is more than a year since we have been able to purchase a single new book. Such an establishment as our own should have a library of 15,000 to 20,000 volumes to begin with, on the branches of mathematics, physics, geodesy and astronomy, and it would require an annual outlay of about one thousand dollars to provide for the merely necessary accessions. It is not as if we were situated near some of the great libraries of the East, so that the works of occasional use only could be omitted from our special collection. On the contrary, it is necessary to possess these. To discover what is new, we must be able to verify what is already known. I am not willing to leave this subject without a grateful acknowledgment of the many valuable gifts to the Observatory library from academies of science, observatories and individual astronomers, both at home and abroad. Through their kindness, the Observatory receives nearly all the current publications by gift and

in exchange, and in very many cases we have been presented not only with current volumes, but with long series of past publications.

It would have been entirely impossible to have put the Observatory into its present efficient condition had it not been for the earnest and whole-hearted coöperation of the Regents of the University and of their Secretary, who have waived all minor technicalities in the way of doing our official business, and have simply inquired whether such and such an action or expense was necessary. The waiver of unnecessary routine has saved at least a year of work to the Observatory, and it ought to be and is gratefully acknowledged by all of us.

Every necessary of life at Mt. Hamilton must be provided by individuals, except water. That is furnished by the Observatory. To distribute this, we have a system of four reservoirs, with several miles of pipes, under and over ground and in the buildings. All the motive power used in revolving the great dome, or in raising its floor, depends on the water-supply, and the slightest accident to the windmill, or to a reservoir, or to the pipes (by freezing or otherwise), stops the work of the great telescope. After every snow-storm a whole day's work, and sometimes more, is necessary to get the revolving parts of the dome into satisfactory working order. The springs supply no more than 300 to 400 gallons of water daily in the dry season, but fifty times as much in the winter; the daily expense varies from 1000 to 1200 (say forty gallons per man per day, including the photographic laboratories, the stables, etc.). This is a relatively small daily individual expense, as will be seen by comparison with other places.* The reservoir capacity is not sufficient to store water enough to carry us through the dry season (June–October). Hence, every year it has been necessary to use for domestic purposes some of the rain-water collected during the winter and stored for use as power. All this water has passed many times through the water-engines and hydraulic rams, and is therefore covered with a heavy film of oil, and is really unfit for use, and produces more or less illness when it is used. But it *must* be used. There is no other. There is absolutely no present remedy. It will be necessary to provide a greater storage or a greater supply. Either of these things can readily be done; but either will require an expense which there is no present way of meeting. In the meantime there is nothing to be done but to make the best of the conditions and to be as prudent as may be in using the available supply. Every day's supply weighs

* Daily expense per individual, in New York, 79 gallons; Chicago, 118 gallons, Boston, 79 gallons; Milwaukee, 155 gallons; San Francisco, 50 gallons.



South Half of Lick Observatory.

(By the courtesy of *Engineering*.)

8000 lbs., and it must be lifted vertically 412 feet, in order to make it available. In one hour's work with the steam-pump we can raise a little over two days' supply. But the smallest leak in pipes or valves anywhere in the system is fatal. Therefore, in the dry season the most careful watch is kept on the various reservoirs, and they are read daily.

I think that the numerous very light earthquakes have much to do with producing the cracks which we find in the walls and the bottoms of our reservoirs. Even the slightest crack must be quickly discovered and stopped, at the risk of imperiling our daily provision.

The supply of fuel must be found somewhere in the neighborhood, and delivered before the roads become too heavy for hauling. It is the present policy not to cut any wood on the reservation, and hence it must be found where best it may, and its delivery hastened as much as possible. During the winter of 1888-9 the only wood available for the Observatory and for the various households was from my private store, which had been ordered in May, but which was not all delivered till the following February! The procrastination of our immediate neighbors has ceased to be annoying. It is majestic—colossal—like a great feature of nature. It must be reckoned with like the inexorable forces of heat, magnetism, gravitation.

During the severe winter of 1886-7, the Lick Trustees were obliged to collect wood along the stage-road, and it was delivered in small parcels, like express packages. Even so, it was impossible to keep the houses warm, and the water froze on the very dining tables! The photographic lens of the great telescope was worked by Mr. Clark in water so cold that it froze where it was not immediately under his hands, and this because no room in the Observatory could then be warmed above the freezing-point.

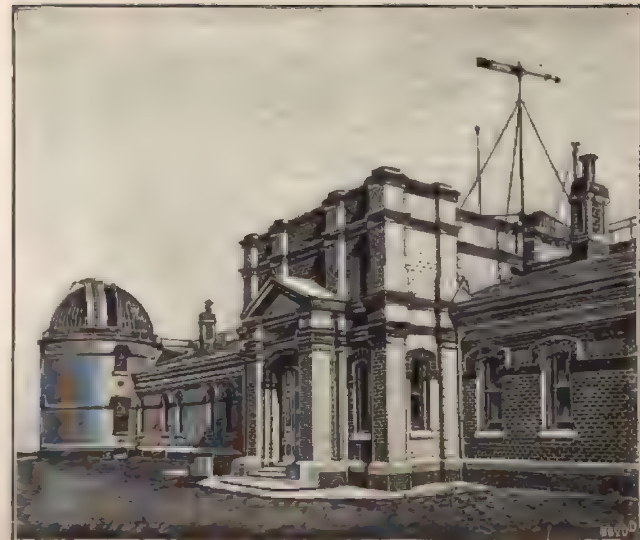
After the fuel has been obtained, it is often a serious problem to keep any fires. Out of six offices there are only two in which a fire can be lighted in all winds. In one of the brick dwellings fires will not burn in a southeast wind, and in the other a north wind is equally fatal. The wind sweeps up the deep cañons on either side, and blows almost vertically down the flues, so that the flames are driven out into the room several *feet!* or else volumes of smoke make it simply impossible to remain in the apartment. Our meals have been served in the halls, in the bedrooms, or not at all! It goes without saying that all sorts of experiments have been tried to cure this defect; a treatise on ventilating chimney-tops could be written from actual examples of discarded patterns now on hand. There is no remedy for this trouble except a rebuilding of the defective chim-

neys themselves on a new plan, and this is now impracticable.

A telegraph line of two wires, seventeen miles in length, connects the Observatory with San José. The distance by the road is twenty-six miles. The Observatory is responsible for maintaining this line, so that its daily time-signals may not fail; and besides this, it is absolutely necessary to maintain the telephone-wire; for all the supplies for the Observatory and for our astronomical colony have to be ordered in San José. Woe to the luckless housekeeper who forgets to order a dinner in time to have it brought up by the stage of that day! Remember it, or do without it, is the stern rule of practice. If, by chance, the stage does not come, or if the driver has forgotten the order, one has only the melancholy satisfaction of having done all that could be done, and one dines a little better for this.

During the summer season everything works easily. There are no heavy winds and no snow-storms, and the telegraph line needs very little attention. Occasionally we hear of a wire broken or a pole down, and must send a laborer to mend it. But in the winter all is different. The snow gathers on the wires and freezes into solid ropes, four or five inches in diameter. The fierce winds blow this mass about, and either break the heavy wires, or tear them off the poles, or even overthrow the poles themselves. There is nothing for it but to equip a wagon with everything that is necessary—ladders, wires, tools, insulators—and to send off two men, for two or more days, to find and repair the damages, which may be miles away from us. During February the telephone line was completely buried under snow and broken in a dozen places for about two weeks, and it was impossible to repair it.* It has been extremely fortunate that no case of serious illness has occurred during any one of our snow blockades. Under the most favorable circumstances we are sufficiently far from medical assistance; and there have been times when no surgeon could have arrived here for several days after the time when he might have been needed. The wind mill at our lowest reservoir (Huyghens) is the source of all our power. It is carefully furled during storms; but once each winter, at least, it is blown far off to leeward, smashing the sixteen-foot wheel. Before the break comes heavy iron pieces, nearly two inches in diameter, must be fractured. This occurs during the gusts of storms where the average wind velocity is sixty-five or seventy miles. I have no doubt that the velocity of these gusts is eighty or more miles. We have had, as yet, no opportunity

* It is now destroyed and useless.



North Half of Lick Observatory.
(By the courtesy of *Engineering*.)

to *measure* such velocities, for our anemometer has always disappeared at the same time,—blown off to leeward. The Chief Signal Officer has been kind enough to lend us an anemometer of a new pattern, copied from the one which was successful on Mount Washington. So far we have not been able to measure the high velocities even with this instrument, for it has frozen fast to its support during the blinding storms of hail, snow and wind.

The problem of providing suitable instruction for the children of the astronomers is a serious one. It has hitherto been solved in various ways—none satisfactory—either by private tuition in the family, or by sending the children away to boarding-schools, or, finally, by maintaining one house on the mountain and one in San José near the schools. This is a very practical question in every respect. Its final solution will, probably, be the establishment of a public school on the reservation itself.

It has been rather an amusing and novel experience to undertake some culture experiments on the mountain. The usual vegetation is a scanty grass, a little wild oats, the scrub oak *(chapparal)*, the Douglas oak, the Digger pine, a few specimens of the golden oak (a beautiful evergreen tree), with stunted manzanitas, Gowrias, and in one place a little patch of wild grapevines. There is no doubt that the nobler varieties of oaks and pines can be made to grow here, together with the chestnut, the cherry, the apple, the plum and other fruit trees. We have found that the Monterey pines and cypresses do capitally; and we take great pride in a little avenue of such young trees, which are now more than a year old. In my own garden I have twelve varieties of roses, which, so far, flourish. Some of the astronomers and students have been really successful in this work, and have quite transformed the appearance of their immediate surroundings. Mr. BARNARD's garden, for example, contains geraniums, violets, mignonette, etc., which do well, with care. Such hardy flowers as marigolds will care for themselves, and we are all proud of the scanty growth of wild oats which has been coaxed into existence on the bare rock of the summit-level.

It is a very practical matter to encourage such growths, for they serve to keep down the dust and to make all our observations in the day-time more accurate by covering up the bare rocks and shielding them from the intense heat of the sun.

The process of planting a young tree is interesting. In the first place, the loose soil, an inch or so thick, is removed, and then the surface of the rock appears. If we go down three or four feet, this

rock is as blue and solid as trap-rock, which it very much resembles when first uncovered. It is, however, nothing but a blue sandstone *(arcose)*, and whenever it is exposed to the air, it rapidly disintegrates. Frequent slight earthquakes and the effects of frost fill the upper and more exposed layers with little cracks. To plant the tree the tolerably solid portion must be attacked, and great masses, two feet or more in diameter, must be removed in single pieces. Finally, we succeed in getting a good-sized cavity, which is then filled with rich soil. The little tree must be protected from the high winds on the windward (southeast) side, and, finally, it must be watered during the dry season. But the sturdy young pines we have already reared amply reward us for all trouble, and they have already changed the aspect of the place. It is a thousand pities that this culture has been neglected until now. There is no reason why the whole vicinity of the summit should not now be covered with pines and chestnuts, and with the nobler varieties of oaks. We must wait another ten years for this to be accomplished. During the last season large quantities of wild-oat seed and of buckwheat have been spread on the barren slopes of the hills, and in a few years these will be covered with a mat of vegetation. A tract of eight or nine acres has been plowed, and is now sowed in oats, barley and rye, and we expect to raise all our own forage in future.

The desolate slopes of the summit, which consist of mere loose rocks, must be covered with some kind of vegetation to consolidate them. Already the outer edges have sunk two feet or more in various places, and we shall soon be reduced to the small platform of solid rock, unless these slopes can be protected by vines and roots. This work, too, has been commenced, and in a few years we hope, at least, to see our slopes saved, and also to see them covered with vines and creepers. At the immediate summit the present rock walls must be soon replaced with brick. Every winter destroys many feet of the present walls, and soon there will be little or none left.

I remember well that when I reported for duty at the Naval Observatory in Washington (where the dome for the great telescope was then building) the first question asked me was not an astronomical, but a practical one, "Do you know how cement ought to be mixed?" In my experience since then I have found that every sort of practical knowledge came into full play in the course of scientific work. At no place could there be a greater demand for it than at the summit of Mount Hamilton. The ingenuity of the extraordinary beings of JULES VERNE's stories would be severely

Lick Observatory from the Cottages.

(By the courtesy of *The Universal Review*.)

taxed to meet the numberless small exigencies of a year. One should be farmer, gardener, engineer, millwright, carpenter, builder, machinist, all in one. I have sought, with a certain measure of success, to obtain something like a numerical estimate of the quantity and variety of things which have been done during the past nineteen months. It is the system at the Observatory to keep a memorandum of the "extra work to be done" on cards, one or more items on a card. At the proper time the card is handed to the person who is to do the work, and, when it is finished, the card is returned. Of course, many of these memoranda are now lost, as they have no permanent value; again, a great many things have been done from verbal instructions alone. Some items call for half an hour's work, while many require a week's labor. Moreover, none of the regular routine work is represented by such memoranda, but only the *extra* work, which, once done, will not have to be done again. I have had the curiosity to have these cards counted, and I find that there still remain 1168 of them, which may correspond to 2000 of the original ones, or to, say, 3000 to 4000 separate items, or to 8000 or more hours of *extra* labor. The Secretary's letter-press copying-books for the same period contain 5100 pages of letters, mostly mere orders for materials for building or repairs. These letters correspond to about 500 working days. More than 650 checques have been issued in payment of bills. Perhaps such very rough statistics will appear trivial to others. To me they seem to stand for milestones, and to have a real value, as showing how far we have come, and, especially, as indicating a road over which, happily, we shall never be forced to travel again.

In what has gone before I have sought to give something like an adequate view of the unofficial, personal and incidental side of life at the summit of our mountain, and to show how closely this personal side is bound up with the official; how the latter, in fact, depends for its value on the good organization of the former. This chapter seems to me to be worth writing, and I hope it will have been of interest to the members of this body who visit Mount Hamilton every year at the regular summer meetings of our Society, and who are therefore familiar with one aspect of the Observatory. I hope, also, that I have avoided presenting too familiar and intimate details; and I hope, still more, that I have not seemed to exaggerate the difficulties of the case into an importance which they do not deserve. They actually exist; they will all be gradually overcome. For the present,

they are part and parcel of our circumstances. To estimate the work of the Observatory rightly, they must be taken into account. I may safely leave it for others to say that they have by no means dismayed our company of astronomers, but that they rather have incited them to new efforts. I shall be glad to have indicated, even thus summarily, a few of the directions in which the Observatory needs and deserves to be helped. If our wants are once known, I feel sure that they will be remedied.

A MECHANICAL THEORY OF THE SOLAR CORONA.

By J. M. Schaeberle.

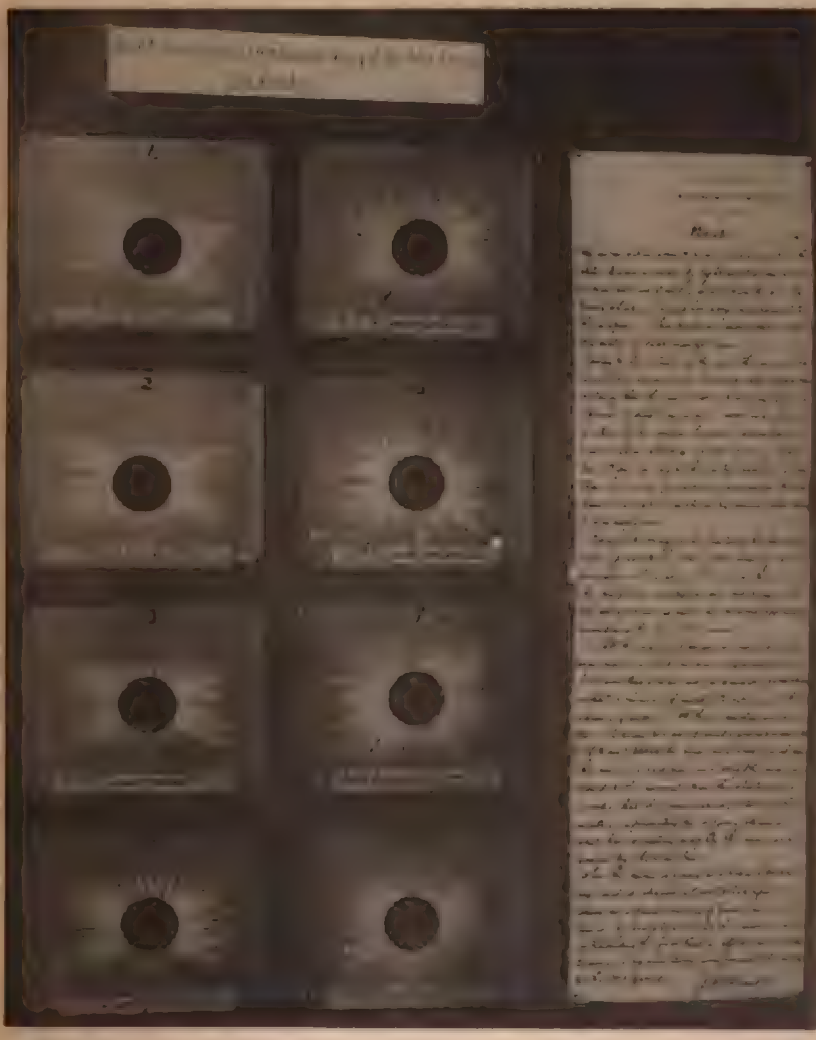
[Abstract.]

Mr. Schaeberle presented a paper entitled "A Mechanical Theory of the Solar Corona." He stated that his investigations seemed to prove conclusively that the solar corona is caused by light emitted and reflected from streams of matter ejected from the sun, by forces which, in general, act along lines normal to the surface of the sun; these forces are most active near the centre of each sun-spot zone.

Owing to the rotation of the sun, the streams of matter will not lie along normals, since the angular velocity of different portions of the stream grows less as the distance from the sun increases; in other words, the streams are of double curvature. Each individual particle of the stream, however, describes a portion of a conic section, which is a very elongated ellipse so long as the initial velocity is less than 383 miles per second (assuming that the sun's atmosphere, as shown by various observations, is exceedingly rare).

The variations in the type of the corona admit of an exceedingly simple explanation, being due to nothing more than the change in the position of the observer with reference to the plane of the sun's equator. *According as the observer is above, below, or in the plane of the sun's equator, the perspective overlapping and interlacing of the two sets of streamers cause the observed apparent variations in the type of the corona.*

Mr. Schaeberle then exhibited a model, in which the sun is represented by a ball about an inch in diameter, from which radiate a number of needles, to represent the streams of matter. All these needles are contained between two zones corresponding to $\pm$ 30° of



latitude. The longer ones are most numerous near the middle of each zone, and slightly more inclined to the normal than the shorter ones, in order that the more distant portions of the needles (representing the outgoing streams) shall have directions roughly the same as required by physical laws. Eight photographs of the model, representing the various types of the corona, were also shown. When the model is placed in a beam of parallel rays and its shadow allowed to fall upon a screen, the slightest change in the position of the model produces an entirely new image. Mr. SCHAEBERLE stated that he had thus far been unable to find a single observed phenomenon which could not be accounted for by this mechanical theory.

A discussion of the theory and a comparison, showing the remarkable agreement with observation, will appear in the Report of the Eclipse of December 21, 1889.

PHOTOMETRY OF THE CORONA OF DECEMBER, 1889.

BY EDWARD S. HOLDEN.

[ABSTRACT.]

Mr. HOLDEN gave an account of the photometric determinations of the actinic brightness of the corona. Two of the plates taken by Mr. BURNHAM and two taken by Mr. SCHAEBERLE were standardized. A preliminary reduction of these plates shows that the brightness of the corona and sky, as measured directly from the plates, will substantially reproduce the results obtained by Mr. W. H. PICKERING at the eclipse of 1886, in Grenada. That is, the brightness of the corona, as measured directly from the plates, will be only about 40 *per cent.* of that obtained from Mr. BARNARD's plates of the California eclipse of January 1, 1889. Mr. PICKERING's plates of 1886 were not developed for several months after the eclipse, and when developed the films were found to have deteriorated. The Cayenne plates showed considerable deterioration, due to dampness, though they were developed immediately after exposure. Precautions were, however, taken, before the eclipse, which will possibly enable us to give a numerical estimate of the amount of change. Besides the eclipse plates ten others (A, B, C, D, E, F, G, H, I, J), were standardized by Mr. BARNARD at the Lick Observatory, on September 24, 1889. A, B, C, D were taken to the eclipse, and E, F, G, H, I, J remained at the Lick Observatory. I and J were

developed on September 24, 1889, immediately after exposure. A and B were developed at Cayenne on December 22, 1889. E and F were developed at the Lick Observatory on the same day. C and D were returned undeveloped to the Lick Observatory (arriving there March 5, 1890). G and H (still undeveloped) and C and D were then re-standardized by Mr. BARNARD (March 16th), and all four were developed together March 17th. Thus, a complete history of the changes of these plates is available; and it is possible that a numerical factor can be obtained by which to multiply the measures of brightness obtained directly from the plates taken at Cayenne, to obtain the results which they would have given, had the eclipse occurred at Mt. Hamilton.

The practical result of this interesting experiment is to show that plates which are to be exposed in a damp climate should be hermetically sealed until they are exposed, and again sealed immediately afterwards. The agreement between the results of Mr. PICKERING'S measures and those of December, 1889, shows that both are erroneous. The measures on the plates of January, 1889, are to be taken as correct, for the present, at least.

NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

INTERNATIONAL CONGRESS OF CELESTIAL PHOTOGRAPHY.

The International Astro-Photographic Congress, which met at Paris in 1888, is now divided into two parts. The first is concerned with the production of the stellar charts of the whole sky; the work of the second relates to the application of photography to the study of the physical conditions of the sun and stars. The first section publishes a *Bulletin* of which four parts (in quarto) have already appeared. The second section has just printed the *Procès-verbaux* of its meetings in September, 1889, and a summary of this important document follows.

Thirty-nine of the sixty-six members of the Congress were present at the sessions, and joined in discussions of the varied questions brought before the meeting. The President, M. JANSSEN, in his opening address, briefly reviewed the field of work, which was then considered in detail. The conclusions of the Congress are here summarized:

Photography of the Sun. It was voted that solar photograms, to be used either for precise measures or for mere statistics of the spots, should be of one size, and a solar image of one decimeter in diameter (3.94 inches) was recommended.

It was recommended that photographs destined for the statistical study of the solar spots should be made at as great a number of observatories as possible, so that, on the average, several negatives should be available each day.

It was voted that the Congress recommends a comparative study of the solar spots and of terrestrial magnetism.

It was voted that the Congress calls the attention of observers to the great present importance of obtaining solar photograms on a large scale at as many stations as possible. A solar diameter of three decimeters (11.8 inches) should be considered as the minimum size of such photograms, taken either for the study of the photosphere, for the determination of the distribution of spots, faculæ, etc., or for the detection of the transits of small bodies revolving about the sun.

It was recommeded that the solar spectrum should be studied photographically, and that this study ought to be extended to the invisible portions of the spectrum; and, also, that a study of the atmospheric solar spectrum should be made for different altitudes of the sun. It was also recommended that observers should study the spectrum of the solar corona by photography (without an eclipse,—*i. e.*, in full daylight).

Photography of the Moon. It was recommended that observatories should secure series of lunar photographs, endeavoring to have as many pictures as possible for the whole duration of a lunation, so as to be able to deduce from them the true topographical features of our satellite. Enlargements were also recommended.

Photography of Planets, Comets, etc. The Congress recommended the study of planets by photography; and encouraged the study of methods for the photography of meteors and shooting stars. With regard to comets, the Congress recommended that they should be photographed so as to obtain a series of images during the whole course of their apparition, and insisted upon the importance of detailed photographs of the heads of such bodies.

Photography of Clusters. It was recommended that clusters of stars should be photographed, as well for the purpose of precise measures of position as for descriptive purposes, and that for such

photographs the processes prescribed for the international charts should be adhered to.

Photometry of Stars. M. JANSSEN described his method for determining the brightness of stars, as follows: The method depends on the proposition that the brilliancies of two lights are inversely proportional to the times required for the two lights to stain a sensitive plate to a given amount,—that is to say, to accomplish equal photographic effects. To apply the method to the stars, a plate is placed *beyond* the stellar focus of the telescope, so as to obtain the diluted disc or circle of the star. This operation is to be repeated a number of times with different exposures for each of the two stars to be compared. The plates for the two stars are to be developed together, and, finally, a diluted disc of star A must be found which will match in intensity some diluted disc of star B. The relative brilliancies of the two stars are, according to M. JANSSEN, inversely proportional to the times of exposures.

Photography of Spectra. The Congress recommended that comparisons should be made between the spectra of the sun and of the stars, using the lunar spectrum as a term of comparison.

Photography of Nebulæ. The Congress recommended, 1st, that photographs of nebulæ should be taken so that they may be comparable with future photographs; and that to this end the most suitable methods should be adopted, notably the method of *diluted discs* (see above); 2d, that methods should be devised for the discovery of nebulæ by photography; 3d, that observatories should prepare "documents," such that any modifications which the negatives may suffer can, in the future, be detected.

Instruments to be Used. The Congress advises that special instruments should be employed for each class of researches; and recommends, in general, reflectors for the photography of nebulæ and comets, and refractors of long focus for the study of clusters and of planets, etc.

Preservation of Negatives, etc. M. JANSSEN stated that negatives on collodion were preserved, at Meudon, by covering them with plain glass, and fastening the two pieces of glass together with lead bands, and the Congress recommended this process for the preservation of negatives, etc.

The Congress also recommended that the negatives obtained by an observatory should, in general, be preserved at that observatory;

but that a certain number of copies should be carefully made (for deposit at certain central bureaus).

The Congress voted that in order to determine the solar parallax, it was of the highest interest to photograph the asteroids at their favorable oppositions.

It was further voted that non-photographic spectroscopy should be included in the subjects of consideration, and that in future the title of the Congress should be *Congrès de Photographie et de Spectroscopie Célestes.*

The adjournment of the session took place on September 26th.

E. S. H.

Earthquake Observations.

The desirability of obtaining accurate records of earthquake disturbances has long been recognized. Services for this purpose are organized in Italy, Switzerland, Japan and California. For the service in California inexpensive but entirely efficient instruments have been made by copying the Duplex Seismometer, which Professor Ewing invented for Japan.

Duplex Seismometer.
(By the courtesy of *Nature*.)

Mr. Mateo Clark, of London, a member of the Society, has recently presented earthquake instruments of this description to the Observatories of Mexico, Santiago de Chili, Cordoba and Greenwich. It is hoped, if these instruments prove to be as satisfactory in their new situations as they have been in California, that they may lead to the establishment of a regular system of such stations in the different countries.

The California system includes two complete seismometric stations, at Berkeley and at Mount Hamilton, and duplex instruments (like the cut) at two points in San Francisco, at Chabot Observatory (Mr. Burckhalter), at Mr. Blinn's private observatory in East Oakland,

at Mills College (Professor KEEP), at the University of the Pacific (Professor HIGBIE), and at the headquarters of the Nevada State Weather Service (Professor FRIEND'S private observatory, Carson). An instrument will soon be set up at the foot of Mount Hamilton. Three more are needed for the Santa Clara valley—at Los Gatos, at or near Menlo Park, at or near San Mateo or San Bruno. If results of value can be attained at all, we must begin by studying the statistics of small regions. Instruments made in California have been furnished also to the United States Geological Survey (Washington), to WARNER & SWASEY (Cleveland), to Captain FLOYD (at Clear Lake), and to the Blue Hill Observatory (Massachusetts). E. S. H.

LIST OF EARTHQUAKES IN CALIFORNIA DURING THE YEAR 1889.

The following paper contains the dates and places of occurrence of earthquakes in California (and occasionally in Nevada) during the past year. When known, the intensity on the ROSSI-FOREL scale is given by Roman numerals enclosed in parentheses. The observations made at Mount Hamilton and reports of the different earthquakes communicated to this Observatory by letter, or published in the newspapers, will probably be printed *in extenso* elsewhere as a continuation of the lists already published by Professor HOLDEN,* containing all available data up to the end of the year 1888.

The instruments at the Lick Observatory give the means of expressing the intensity of an earthquake shock in terms of the maximum acceleration produced by the motion of the earth's surface; and it is one of the principal objects of the observations to obtain data for the comparison of the intensity determined in this way with that expressed in the ordinary terms describing the effects of earthquakes. This relation, when once established, will allow the intensity of earthquake-shocks to be stated according to a definite scale, with much greater accuracy than is possible at present. Provisional tables for the purpose have been given by Professor HOLDEN.†

A duplicate set of the instruments used at the Lick Observatory is mounted at the Students' Observatory at Berkeley, in charge of Professor SOULÉ. Seismographs of simpler pattern, which register the horizontal, but not the vertical, motion, and give no record of the

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* *List on Recorded Earthquakes in California, Lower California, Oregon and Washington Territory.* (Sacramento: State Printing Office. 1887.)

Earthquakes in California (1888). *American Journal of Science*, Vol. XXXVII, May, 1889.

† *Note on Earthquake-Intensity in San Francisco* (*American Journal of Science*, Vol. XXXV, June, 1888).

time, are mounted at a number of stations distributed throughout the State. Of these, reports were received in 1889 from the following places:

Students' Observatory, Berkeley, in charge of Professor Soulé.

Chabot Observatory, Oakland, in charge of Mr. Burckhalter.

Private Observatory of Mr. F. G. Blinn, in East Oakland.

Observatory of the University of the Pacific, San José, in charge of Professor Higbie.

Observatory of Mills College, in charge of Professor Keep.

Office of State Weather Bureau, Carson (Nevada), in charge of Professor Friend.

1889. *List of Earthquakes.*

Jan. 19, 1:43 A. M. Oakland (II).

Jan. 22, 7:51:58 P. M. Mt. Hamilton (I?).

Feb. 6, 9:20 P. M. Southern California. San Bernardino (VI), Colton, Los Angeles.

Apr. 3, 2:29 A. M. Mt. Hamilton (II).

Apr. 14, 7:28 P. M. Central California. Lick Observatory (III). San José, Santa Cruz, Centerville, Los Gatos, Gilroy, Merced, Oakland.

Apr. 17, 8:32:38 P. M. Mt. Hamilton (I).

Apr. 20, 4 A. M. San José.

May 1, 11:55 A. M. Lompoc.

May 1, 9 A. M.? P. M.? Susanville.

May 19, 3:10 A. M. Central California. Mt. Hamilton (V), Berkeley, Oakland (VI), East Oakland (VI), Collinsville (VII), Mills College, San Francisco, Forest Hill, San José, Stockton, Lodi, Antioch, Modesto, Napa, San Leandro, Petaluma, Rio Vista, Newark, Nevada City, Calistoga, Vacaville, Santa Cruz, Sacramento, Mountain View, Pleasanton, Haywards, Los Gatos, Fairfield, Woodland, Santa Rosa, Ione, Suisun.

May 26, 7:13 A. M. Central California, Mt. Hamilton (II). San Francisco, Gonzales, Santa Cruz.

June 6, 4 A. M. Oakland (II).

June 6, 8:30 P. M. San Bernardino (III).

June 9, 3:44:24 P. M. Mt. Hamilton (I).

June 10, 7:33:7 A. M. Mt. Hamilton (II).

June 19, 10 P. M. Lassen county, California and Nevada. Susanville, series of shocks; Chico, Sacramento. Downieville, Grass Valley, Carson City (Nev.).

June 20. Susanville, shocks during the day.

June 20, P. M. San José.

June 24, about 4 A. M. San José.

June 25, 3 A. M. San Diego, Carson City, Nev. (III).

June 27–28, during night. Carson City, Nev.

June 30, between 8 and 10 A. M. Carson City, Nev. (II) or (III).

July 2–3, during night. Carson City (II).

July 4, 8:05 A. M. Carson City, Nev. (II).

July 4–5, during night. Carson City.

July 6–7, during night. Carson City.

July 9–10, during night. Carson City.

July 10, and preceding days. Arroyo Grande, San Luis Obispo county, a number of shocks.

July 25, 10:8:0 P. M. Mt. Hamilton (IV–V).

July 31, 4:46:45 A. M. Mt. Hamilton (V), Oakland, East Oakland (VI)), Berkeley, San Francisco, San José, Sacramento, Napa, Petaluma, Martinez, Gilroy, Santa Cruz, Centerville, Los Gatos, Santa Rosa, Benicia, Newark, Concord, San Leandro.

July 31, 6:19:39 P. M. Oakland (I).

Aug. 7, 3:42:11 P. M. Mt. Hamilton (?), suspected (I ?).

Aug. 13, 4:43 A. M. Oakland (III–IV).

Aug. 23, 2:32:47 P. M. Mt. Hamilton (I).

Aug. 27, 6:15 P. M. Southern California, San Bernardino (III), Pomona (VI–VII), Los Angeles (VI), Santa Ana, Santa Monica, Pasadena.

Sept. 24, 8 A. M. Napa, Winters, Woodland.

Sept. 29, 8–10 P. M. Wawona, Kingsbury.

Sept. 30, 12:17:30 P. M. Kingsbury.

Oct. 24, 7:20 A. M. East Oakland (II).

Nov. 14, 6:54 P. M. San Lorenzo.

Nov. 15, 7:55 P. M. East Oakland (II), Healdsburg.

Dec. 2, 6:30 P. M. East Oakland. J. E. K.

Determination of the Longitude of Mt. Hamilton.

Bulletin No. 13 of the U. S. Coast and Geodetic Survey (Oct. 7, 1889), gives the results of a longitude campaign made by Messrs. Sinclair and Marr, of the Survey, during October and November, 1888. The results are:

	h.	m.	s.	
Lafayette Park Station, S. F., ...	8	9	42.77	W. of Greenwich.
Mt. Hamilton C. Survey Station, . .	8	6	33.72	" "
Mt. Hamilton (Lick Observatory), . .	8	6	34.81	" "

The probable error (estimated) is about $0^s.1$.

The latitude observations made at the same time were not entirely satisfactory, and will be repeated. They indicate, however, that the difference between the astronomical and geodetic latitude is not much above 1″ of arc. E. S. H.

THE RED SPOT ON *JUPITER*.

A very useful work could be done by any member of the Society who has the leisure for it, by computing the times when the meridian of *Jupiter* passing through the red spot was turned towards the earth, in the years *before* 1878 (the date of its discovery). The invaluable ephemerides for physical observations of *Jupiter* which are published annually by Dr. MARTH make this calculation a simple one for many years past. The drawings of the planet previous to 1878 should be examined, in order to study the appearance of the belt on which the red spot is situated and to detect the *first* appearance of a disturbance in this region. There is reason to believe that as early as 1857 DAWES described an appearance of the sort.

The present note is written to call attention to a very remarkable drawing of the planet made on January 5, 1870, by Professor MAYER (*Journal of the Franklin Institute*, February, 1870, page 136), which has escaped attention hitherto. This drawing shows an elliptical ring which strikingly suggests the red spot in form and position. It was central at 8^h, Bethlehem (Lehigh University) mean time, on January 5, 1870. So far as I know, the work suggested is not now in hand.

E. S. H.

TABLE OF CONSTANTS RELATING TO THE SUN AND TO THE MOON.

The following tables, reprinted from YOUNG'S *The Sun* and from NEISON'S *The Moon*, may be found convenient for reference.

A. J. B.

Solar Statistics.

(From YOUNG'S *The Sun*, page 278.)

Solar parallax (equatorial horizontal): 8.80″ ± 0.02″.

Mean distance of the sun from the earth: 92,885,000 miles; 149,480,000 kilometres.

Variation of the distance of the sun from the earth between January and June: 3,100,000 miles; 4,950,000 kilometres.

Linear value of 1″ on the sun's surface: 450.3 miles; 724.7 kilometres.

Mean angular semidiameter of the sun: 16′ 02.0″ ± 1.0″.

Sun's linear diameter: 866,400 miles; 1,394,300 kilometres.*

Ratio of the sun's diameter to the earth's: 109.3.

* This may, perhaps, be *variable* to the extent of several hundred miles.

Surface of the sun compared with the earth: 11,940.

Volume, or cubic contents, of the sun compared with the earth: 1,305,000.

Mass, or quantity of matter, of the sun compared with the earth: 330,000 ± 3,000.

Mean density of the sun compared with the earth: 0.253.

Mean density of the sun compared with water: 1.406.

Force of gravity on the sun's surface compared with that on the earth: 27.6.

Distance a body would fall in one second: 444.4 feet; 135.5 metres.

Inclination of the sun's axis to the ecliptic: 7° 15′.

Longitude of its ascending node, 74°.

Date when the sun is at the node: June 4–5.

Mean time of the sun's rotation (Carrington): 25.38 days.

Time of rotation of the sun's equator: 25 days.

Time of rotation at latitude 20°: 25.75 days.

Time of rotation at latitude 30°: 26.5 days.

Time of rotation at latitude 45°: 27.5 days.*

Linear velocity of the sun's rotation at his equator: 1.261 miles per second; 2.028 kilometres per second.

Total quantity of sunlight: 6,300,000,000,000,000,000,000,000,000 candles.

Intensity of the sunlight at the surface of the sun: 190,000 times that of a candle flame; 5,300 times that of metal in a Bessemer converter; 146 times that of a calcium-light: 3.4 times that of an electric arc.

Brightness of a point on the sun's limb compared with that of a point near the centre of the disk: 25 per cent.

Heat received per minute from the sun upon a square metre, perpendicularly exposed to the solar radiation, at the upper surface of the earth's atmosphere (*the solar constant*): 25 calories.

Heat-radiation at the surface of the sun, per square metre per minute: 1,117,000 calories.

Thickness of a shell of ice which would be melted from the surface of the sun per minute: 48.5 feet; or 14.75 metres.

Mechanical equivalent of the solar radiation at the sun's surface, continuously acting: 109,000 horse-power per square metre; or 10,000 (nearly) per square foot.

Effective temperature of the solar surface (according to ROSSETTI): about 10,000° Cent.; or 18,000° Fahr.

Lunar Elements.

(From NEISON'S *The Moon*, page 567.)

TABLE III.

Synodical revolution: 29.5305887 days; $29^{d}\ 12^{h}\ 44^{m}\ 2^{s}.684$.

Sidereal revolution: 27.3216614 days; $27^{d}\ 7^{h}\ 43^{m}\ 11^{s}.545$.

Tropical revolution: 27.321582 days; $27^{d}\ 7^{h}\ 43^{m}\ 4^{s}.68$.

Anomalistic revolution: 27.55460 days; $27^{d}\ 13^{h}\ 18^{m}\ 37^{s}.44$.

Nodical revolution: 27.21222 days; $27^{d}\ 5^{h}\ 5^{m}\ 35^{s}.81$.

Distance (mean): 60.27035 of earth's radii; 238,840.25 miles.

Distance (maximum): 252,972 miles.

Distance (minimum): 221,614 miles.

Diameter (mean): 31′ 8″.00; 2163.06 miles.

Diameter (maximum): 33′ 33″.20.

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* These last four numbers are somewhat doubtful, the formulæ of various authorities giving results differing by several hours in some cases.

Diameter (minimum): 29′ 23″.65.

Mass: $\left\{\begin{matrix} 0.01228 \\ \frac{1}{81.46} \end{matrix}\right\}$ of the earth's.

Revolution of perigee (mean): 3232.575 days; 8.8505 years.

Advance of perigee each year (mean): 40° 40′ 31″.1.

Revolution of nodes (mean): 6793.391 days; 18.5997 years.

Regression of nodes each year (mean): 19° 21′ 18″.3.

Maximum geocentric libration in longitude: 7° 53′ 51″.0.

Maximum geocentric libration in latitude: 6° 50′ 45″.0.

Maximum parallactic libration: 1° 1′ 35″.0.

Maximum geocentric libration: 10° 25′ 22″.0.

Maximum libration (total): 11° 25′ 30″.

Surface of the moon never seen: .4100.

Surface of the moon that is visible at one time or another: .5900.

Angle subtended by one degree of selenographical latitude and longitude at the centre of the moon's disc, when at its mean distance: 16″.566.

Length in miles of the same: 18.871.

Selenographical arc at centre of the moon's surface, subtending an angle of one second of arc: 3′ 37″.31.

Miles at the centre of the moon's disc subtending an angle of one second of arc: 1.139.

Surface: $\left\{\begin{matrix} 0.074478 \\ \frac{1}{13.43} \end{matrix}\right\}$ of the earth's.

Volume: $\left\{\begin{matrix} 0.02033 \\ \frac{1}{49.18} \end{matrix}\right\}$ of the earth's.

Density: $\left\{\begin{matrix} 0.60419 \\ \frac{1}{1.655} \end{matrix}\right\}$ of the earth's (water being unity).

Action of gravity at the surface: $\left\{\begin{matrix} 0.16489 \\ \frac{1}{6.065} \end{matrix}\right\}$ of the earth's.

Horizontal parallax (constant of): 57′ 2″.325.

Eccentricity of orbit (mean): 0.05490807.

Inclination of orbit (mean): 5° 8′ 39″.96.

Inclination of axis to ecliptic: 87° 27′ 51″.0.

Inclination of equator to ecliptic: 1° 32′ 9″.0.

Inequalities in the moon's longitude—

Equation of the center (maximum): 6° 17′ 19″.06.
Evection (maximum): 1° 16′ 27″.01.
Variation (maximum): 39′ 30″.70.
Annual equation (maximum): 11′ 9″.00.
Parallactic equation (maximum): 2′ 4″.70.

Inequalities in the moon's latitude—

Evection: 8′ 57″.37.
Variation: 33″.44.

Announcement of the Discovery of the Rotation Period of *Mercury*, by M. Schiaparelli.

On the 8th of December, 1889, the *Accademia dei Lincei*,* of Rome, held a special sitting, which the King and Queen of Italy

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* Galileo was one of the original members of this Academy (*dei Lincei*—of the Lynxes—of the sharp-eyed ones), which was named after the fantastic manner of the day.

attended, in order to hear a discourse by M. SCHIAPARELLI on his discovery of the rotation period of the planet *Mercury*.

From a report of this meeting and from a short paper in the *Astronomische Nachrichten*, the following brief account is condensed.

The rotation periods of the planets *Mercury* and *Venus* must be fixed, if at all, by the observation of the spots on their surfaces. Neither of these planets is ever to be found at any considerable angular distance from the sun, so that they must be observed in the twilight or in the daytime. At all observatories the images of planets in the daytime are wavering and unsteady, and at some stations (as at the Lick Observatory, for example,*) daylight observations can almost never be made to advantage. At Milan, M. SCHIAPARELLI has been able to observe *Mercury* some 150–200 times in the years 1881–6 with the eight-inch telescope; and since that time he has used the eighteen-inch telescope, which has confirmed his earlier conclusions.

The fundamental facts relating to the rotation of the planet are:

I. If *Mercury* is observed on two consecutive days, the aspect of its spots is identical or nearly so; and the same is true when the interval between observations is two, three or four days, etc. This fact of observation can be explained by either one of three hypotheses —(*a*) the rotation period of *Mercury* is about twenty-four hours; (*b*) or the planet makes two or more rotations in this period; (*c*) or the rotation is so slow that an interval of two or three days makes no appreciable alteration in the position of the markings.

II. The observations at Milan showed Professor SCHIAPARELLI, to his satisfaction, that the motion of the spots on the apparent disc was too slow to permit of the possibility of the hypotheses *a* or *b*. It followed, therefore, that the rotation period was of *many* days.

III. Observations in 1882–3, confirmed in 1886–7, showed that the planet revolved about the sun at least somewhat as the moon revolves about the earth, namely: in turning always the same face, or nearly the same face, to the primary body. The observations themselves were so difficult that it was impossible to prove that *Mercury* revolved on its axis *exactly* in the period of one revolution in its orbit (as in the case of the moon). Professor SCHIAPARELLI takes the sidereal period of *Mercury* (87.9693 days) at once as its rotation time, although his observations might be satisfied by a period some four hours or so different from this, longer or shorter.

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*See *Publications of the Astronomical Society of the Pacific*, Vol. II, p. 27.

IV. The observations were too difficult to permit the determination of the position of the rotation axis, but all his drawings agree with the assumption that the axis of rotation is approximately perpendicular to the plane of the orbit. It is certain that the axis is not inclined as much as 23° or 25° (like the earth's or *Mars'*), and it is not likely that the inclination varies from 90° by as much as 8°.

V. All the observations tend to demonstrate that the rotation of the planet on its axis is uniform; from which datum, combined with the notable eccentricity of *Mercury's* orbit, it follows that there must be a large libration in longitude with respect to the radius-vector. The period of this libration is eighty-eight days, and its amplitude is twice the maximum equation of the center, or 47° 21′.

The author dwells on the extreme difficulty of seeing the faint markings at all, and of depicting them when seen, but gives a planisphere of the hemisphere turned towards us. On the equator three points are marked O (center of the disc) and two points A and B, 23° 41′ from O, and on either side of it. O is the point turned towards the sun (the point which has the sun in the zenith) at the times of perihelion and aphelion; A and B are the two points which have the sun in the zenith at the times of greatest positive or negative libration.

Considering the difficulty of seeing the spots on *Mercury* at all, it is not easy to give any well-founded opinion as to their nature. They may simply depend upon the diverse materials and the structure of the solid strata of the surface, as in the case of our own moon. But, as *Mercury* is known to have a dense atmosphere, Professor SCHIAPARELLI thinks that it would not be unreasonable to conclude that they might be analagous to our own seas. With regard to this point, he says: "We have in the case of *Mercury* (as in *Mars*), a world which is sufficiently diverse from our own; which receives light and heat from the sun, not only in a greater amount but in a different manner from the earth; and where life, if so be life exists there, finds conditions so different from those to which we are accustomed that we can scarcely imagine them. The perpetual presence of the sun almost vertically above certain regions, and its perpetual absence from other regions, appears to us to be something intolerable. But we must recollect that such a contrast should produce an atmospheric circulation which is at the same time stronger, more rapid and more regular than that which sows the elements of life on the earth; and that on this account it may come about that an equi-

librium of temperature which is far more complete than with us is produced over all the planet."

The foregoing is a very brief summary derived from the important and elegant papers which have already been published in advance of the more elaborate memoir in which Professor SCHIAPARELLI will discuss all his observations for the years 1881–1889. As early as 1882, M. SCHIAPARELLI announced to one of his correspondents (M. TERBY) his discovery in the verses which follow :

Cynthiæ ad exemplum versus Cyllenius axe
Æternum noctem sustinet, atque diem :
Altera perpetuo facies comburitur æstu,
Abdita pars tenebris altera Sole caret.

* * * * *

In 1888, Professor SCHIAPARELLI asked the attention of the astronomers of the Lick Observatory to the inferior planets, and Mr. SCHAEBERLE, Mr. BARNARD and myself have observed *Venus* and *Mercury* in the daytime on a very great number of occasions with the meridian-circle and with the twelve-inch equatorial, but with little success. For reasons which I have given in full in the Hand-book of the Lick Observatory (page 26), we shall never be able to make delicate observations in the daytime at Mt. Hamilton. A station on one of the very small coral islands of the South Pacific Ocean has the very best conditions for this class of observations,* and a mountain observatory has the very worst. On only one occasion during the past two years was it worth while to turn the great telescope upon *Venus* in the daytime, and for a very few moments the view was somewhat better than it had been in the twelve-inch.

If the observations of M. SCHIAPARELLI require confirmation, an expedition to one of the smaller *atolls* of the Pacific would yield the surest and the quickest results.

E. S. H.

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* As is evident, *a priori*, and as I had occasion to learn practically during my stay on Caroline Island, in April and May, 1883.

MINUTES OF THE MEETINGS OF THE BOARD OF DIRECTORS, HELD IN SAN FRANCISCO MARCH 29, 1890.

Mr. HOLDEN in the Chair. A quorum was present.

The minutes of the last meeting were read and approved.

W. H. MAW, of London, J. EWEN DAVIDSON, of Branscombe, Mackay, Queensland, and ANDREW GREIG, of Tayport, Scotland, were elected to life membership, subject to the action of the Society.

A deed was received from Hon. JOSEPH A. DONOHOE, conveying the dies for the DONOHOE Comet Medal, and ten finished medals, accompanied by a letter, stating that the principal of the Medal Fund had been deposited (bank book No. 51,529) in the San Francisco Savings Union, January 1, 1890. An acknowledgement from the bank to receiving the fund accompanied the letter. Received and ordered on file.

The Library Committee reported that a number of books had been ordered.

Bills to the amount of $74.40 were ordered paid.

The resignation of W. C. GIBBS was received and accepted.

The following resolutions were adopted:

Resolved, That the Committee on the Comet Medal is authorized to make any arrangements for striking the medals which may seem best, and to send the dies abroad, if necessary.

Resolved, That designs for a seal for the Society be procured.

Resolved, That the Committee on Publication is instructed to print the publications of the Society and to distribute them, according to the present system, until further orders.

Resolved, That the list of Corresponding Observatories and Institutions, as printed in *Publ.* A. S. P., No. 7, is authorized.

The Directors then adjourned.

A meeting of the newly elected Board of Directors was held immediately upon the adjournment of the meeting of the Society, and the officers and committees for the year were elected, according to the lists printed on the last page of the present number of the publications.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD (BY INVITATION) AT THE CALIFORNIA ACADEMY OF SCIENCES' BUILDING, SAN FRANCISCO, MARCH 29, 1890.

The President in the Chair.

The minutes of the last meeting were read and approved.

The thanks of the Society were returned to the California Academy of Sciences for the use of their rooms.

Twenty-three new members were elected. (Their names are printed in the present number on page 89.)

The Committee on Nominations reported a list of names proposed for election, as follows:

For Directors: Messrs. ALVORD, BURCKHALTER, GRANT, HILL, HOLDEN, MOLERA, PIERSON, SCHAEBERLE, SOULÉ, WYTHE, ZIEL.

For Committee on Publication: Messrs. HOLDEN, KEELER, YALE.

Messrs. MCCONNELL and ZIEL were appointed as tellers. The polls were open from 8 to 9 o'clock, and the persons above named were duly elected.

The Secretary reported that seventy-five presents had been received since the last meeting, and the thanks of the Society were voted to the givers.

The Treasurer then read his annual report, as follows:

RECEIPTS TO MARCH 29, 1890.

From dues	$2,145 00	
From sale of publications	2 00	
		$2,147 00

CURRENT EXPENSES TO MARCH 29.

For publications	$ 646 45	
For other purposes	379 80	
	$1,026 25	
Cash in bank	1,120 75	
		$2,147 00

FUNDS.

DONOHOE Medal Fund	$ 500 00	
MONTGOMERY Library Fund	2,500 00	
	$3,000 00	
Cash in bank	1,120 75	
Total cash on hand		$4,120 75

The committee appointed to audit the Treasurer's accounts, reported as follows:

"Your committee appointed to audit the accounts of the Treasurer, have made an examination of said accounts from the commencement of his term to the present date, and find them to be entirely correct.

"SAN FRANCISCO, March 29, 1890.

"(Signed) GEO. H. STRONG, Chairman,
EDWARD S. GRAY,
CHASE GITCHELL."

The report was accepted and adopted, and the committee was discharged.

A communication from Messrs. F. H. HAUSMAN and J. G. JONES was read, proposing that the Society establish an Observatory in San Francisco for the use of the members. A committee of three was appointed, to report on this subject at the next meeting. Messrs. HAUSMAN, JONES and PIERSON, Committee.

The President again called the attention of the photographers of the Society to the matter of photographing the Moon in the day time, and expressed the hope that the subject might receive their attention. (See *Publ.* A. S. P., Vol. I, page 32.)

The Society was informed that a CLARK telescope was for sale, and that Mr. N. E. BECKWITH, of Los Gatos, could furnish particulars of its size and of its cost.

The following papers were announced:

a. "Die Astronomische Gesellschaft," by Dr. H. KREUTZ, of the Observatory of Kiel.

b. "The Orbit of μ^2 *Herculis*," by A. O. LEUSCHNER.

c. "On the Similarity of Certain Asteroid Orbits," by Prof. DANIEL KIRKWOOD, LL. D.

d. Annual Address by the retiring President.

e. Account of the Observations of the Total Solar Eclipse of December 22, 1889, by Prof. J. M. SCHAEBERLE.

The latter only was read. The papers are printed in the present number.

The Society then adjourned.

List of Members, January 25, 1890.*

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Prof. JOSEPH LE CONTE, LL.D.	Berkeley, Cal.
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JOHN TEBBUTT, F. R. A. S.	*Observatory, Windsor, New South Wales.*
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Mrs. HARRIET F. WRIGHT,	1111 Corona Street, Denver, Colorado.

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Observatory, Algiers, Africa.
Lawrence Observatory, Amherst, Mass.
Detroit Observatory, Ann Arbor, Michigan.
Library, University of California, Berkeley, Cal.
Redaction Berliner Jahrbuch, Berlin, Germany.

Royal Observatory, Berlin, Germany.
Gesellschaft Urania, Berlin, Germany.
Observatory, Berne, Switzerland.
University Observatory, Bonn, Germany.
Observatory, Bordeaux, France.
Royal Observatory, Brussels, Belgium.
University Observatory, Cambridge, England.
Harvard College Observatory, Cambridge, Mass.
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University Observatory, Christiania, Norway.
University Observatory, Cincinnati (Mt. Lookout), Ohio.
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University Observatory, Dorpat, Russia.
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Observatory, Marseilles, France.
Observatory, Melbourne, Australia.
Stanford University, Menlo Park, Cal.
Royal Observatory, Milan, Italy.
University Observatory, Moscow, Russia.

Lick Observatory, Mt. Hamilton, Cal.
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Royal Observatory, Naples, Italy.
Observatory, Neuchâtel, Switzerland.
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Royal Observatory, Palermo, Italy.
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Astronomical Society, Paris, France.
National Observatory, Paris, France.
Lord Rosse's Observatory, Parsonstown, Ireland.
Astrophysikalisches Institut, Potsdam, Germany.
University Observatory, Prague, Austro-Hungary.
Halstead Observatory, Princeton, New Jersey.
Imperial Observatory, Pulkowa, Russia.
Observatory, Rio de Janiero, Brazil.
Observatory of the Roman College, Rome, Italy.
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Mercantile Library, S. F., Cal.
Mechanics' Institute Library, S. F., Cal.
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University Observatory, Strassburg, Germany.
Observatory of Sydney, New South Wales.
National Observatory, Tacubaya, Mexico.
University Observatory, Tokio, Japan.
Observatory, Toulouse, France.
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Smithsonian Institution, Washington, D. C.
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NOTICE.

Members are requested to preserve the copies of the Publications of the Society as sent to them. Once each year a title page and index of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume.

It is intended that each member of the Society shall receive a copy of each one of the Publications for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied.

Complete volumes for past years (preceding the calendar year in which any member was elected) will also be supplied to members, so far as the stock in hand is sufficient, on the payment of one dollar to either of the Secretaries.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," at the rooms of the Society, 408 California Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. II. SAN FRANCISCO, CALIFORNIA, MAY 31, 1890. No. 8.

ECLIPSE OF DECEMBER 21, 1889.

BY EDWARD S. HOLDEN.

The following extracts from the forthcoming Eclipse Report may have sufficient interest to justify their publication in advance of the main volume. They should be read in connection with preliminary reports on the negatives secured by the British parties, which are given in *The Observatory* for March, 1890, (page 105 (with a plate), and in the *Monthly Notices*, R. A. S., volume 50, pages 219 and 265:

"DIMENSIONS OF THE CORONA.

There are four main wings to the corona. For the purpose of describing them, I have used the following nomenclature:

I	is the	N.	edge	of the	N.	wing	on the	W.	side	of the	sun.
II	"	S.	"	"	N.	"	"	W.	"	"	"
III	"	N.	"	"	S.	"	"	W.	"	"	"
IV	"	S.	"	"	S.	"	"	W.	"	"	"
V	"	S.	"	"	S.	"	"	E.	"	"	"
VI	"	N.	"	"	S.	"	"	E.	"	"	"
VII	"	S.	"	"	N.	"	"	E.	"	"	"
VIII	"	N.	"	"	N.	"	"	E.	"	"	"

I have measured on the negatives the distance from the moon's centre to the point where each of these faint edges terminates. The measures are entirely independent. It will be seen from the table below that the further one goes from the moon's centre the wider apart are the edges VIII and V.

TABLE I.—U. S. N. O. CAMERA NEGATIVES.

Negative.	Exposure.	Distance from the centre of the Moon to extreme point of the faint edge VIII.	Distance from the centre of the Moon to extreme point of the faint edge V.	Distance between the edges VIII and V at the distance from the Moon's centre given in column VIII.	Distance from the centre of the Moon to extreme point of the faint edge IV.	Distance from the centre of the Moon to extreme point of the axis of the wing I and II.
	Sec.	′	′	′	′	′
1*	5	82	86	46	77	72
2*	10	71	71	40	66	70
3	15	82 ±	85	46	72	71
5	20	77 +	85	41	82	77
7†	23 ±	53	57	. .	63	62
		SIX-INCH CLARK TELESCOPE NEGATIVES.				
1‡	2	telescope	jarred.			
2	5	68	67	42	55	60
3	7	70	77	39	60	58
4‡	10	56	67	35	52	60
5	25	60	70	42	65	62
Last §	(?)	2–3	2–3	. .	2–3	2–3

EXTENSION OF THE OUTER CORONA.

The negatives of the December eclipse might not, of themselves, lead to the suspicion of the existence of this feature. The exact evidence which they yield is presented in Table I.

On the other hand, when these negatives are examined with the special object of finding such a feature, they yield no evidence against it. In fact, they show that the outer corona is some 45′ wide at 80′ from the moon's center, and that the beginning of the trumpet-shaped form is present. While it is to be regretted that the December negatives are not decisive on this point, this has little or nothing to do with the evidence upon which the existence of the extension of the outer corona rests.

I may be permitted to recapitulate this evidence, as follows: All of Mr. BARNARD's negatives of January, 1889, show a strongly marked

* Negatives 1 and 2 were standardized. † The Sun came out on 7 after III contact.

‡ Plates 1 and 4 were standardized. § Plate "Last" was spoiled by the sun coming out on

divergence in the edges of the outer corona beyond the 55′ circle, and his negative "C" enables us to trace this trumpet-shaped extension to 75′ or so. The negatives of Messrs. LOWDEN and IRELAND show the same outlines to 130′ and more.

The negatives of Father CHARROPPIN show the same thing, in a beautiful manner, out as far as 100′ or more. The same extension is more or less plainly shown on the negatives of Messrs. DORNIN, JOHNSON, TREAT, PASSAVANT, GRIMWOOD, LANGE, BURCKHALTER and TABER. These negatives were made by eleven different instruments at four widely-separated observing stations. Moreover, the naked-eye drawing of Miss TREAT shows the same feature exactly. It therefore appears to be certain that the extension of the outer corona first photographed in January, 1889, has an objective existence. The negatives of December, 1889, are not sufficient to prove the existence of such a feature; but, so far as they give any evidence at all, they confirm that obtained in the previous January.

The Eclipse Committee of the Royal Astronomical Society considered it "doubtful whether this extension has been photographed," and made a programme for the December eclipse which was designed to decide the question. It appears to have been the idea of the committee that with two instruments of different light-ratios, $^a/_f$, the extension would necessarily be greater (for the same exposure) in that instrument having the greater light-ratio. In their *Report* (*Mon. Not.*, R. A. S., vol. 50, p. 4) it is said: "The failure of exposures of say three minutes to give a sensibly greater extension than one minute, is adduced by Captain ABNEY as a reason for believing the evidence to be, on the whole, against the reality of coronal streamers." Special mirrors were constructed, of aperture 15 inches, focus 45 inches, for use at the December eclipse; "the chief point in the use of the mirrors is to get long-exposure pictures. Short exposures will also be of interest, but the question the mirrors were built to settle is the reality of the coronal extension" (by employing long exposures). In the *Monthly Notices* (vol. 50, p. 220 and p. 271) the Secretary of the Eclipse Committee has given a preliminary account of the negatives secured by the use of the mirrors above described ($^a/_f = 1/3$) and of cameras ($^a/_f = \frac{1}{18}$). The plates taken with the mirrors showed no greater extension than those taken with the cameras. "This result, however, does not appear to be conclusive; the failure of the fifteen-inch mirror to show more than the four-inch lens may apparently be due to some accidental and purely instrumental circumstance, * * * and is really a failure in instrumental

power and not in the light of the object photographed. It cannot be said that any definite conclusion has been arrived at with regard to the extension. It is almost certain that for some cause the twenty-inch mirror was not efficient on the occasion of the eclipse, and it is probable that it was dewed. With an effective aperture of fifteen inches, the short-exposure plates should have shown much more if the mirror had been in its normal state. Hence the failure to photograph the corona more than about a diameter from the limb in forty seconds cannot be taken as evidence against the possibility of photographing 'the extension' in the future" (with long exposures).

It appears to me that the questions involved should be regarded in a somewhat different way. If it is desired to photograph a faint nebula or star on the background of a perfectly dark night-sky, the method above suggested is the appropriate one. If, however, it is wished to record the slight contrast between the corona and a sky which is by no means dark, it must necessarily fail, as can readily be proved by attempting to photograph light, fleecy clouds near the sun (when the latter is temporarily covered by a cloud) in a daylight sky. Even with quite short exposures, the slight contrasts are lost, and longer exposures give a uniform background. As an example, I may refer to experiments by Mr. BURNHAM (with a camera $a = \frac{3}{4}$ inch, $f = 9$, stop $= \frac{f}{12}$, plate Seed 26) on photographing fleecy clouds near the totally obscured sun (which was about twenty-five degrees above the western horizon). He took four plates with times of one-fourth, one-eighth, one-sixteenth and one-thirty-second of a second. The plates were from the same box, and were developed together. There is very great improvement in the faint contrasts of cloud and fog as the time becomes shorter and shorter, and there is no doubt that a time of one-sixty-fourth second or less would have given even better results.*

The visual contrast between a faint nebula and a very dark sky may be the same as the contrast between a fairly bright corona and a fairly bright sky, and yet the two objects must be photographed according to different methods. The dark sky has little or no effect on the plate, and therefore the greater the light-ratio of the camera and the longer the exposure, the more of the nebula is shown. On the other hand, the sky at a total eclipse is actinically fairly bright (about one-tenth as bright as the polar rays in January, 1889), and if the camera has a great light-ratio and the exposure is prolonged be

* These plates are preserved at the Lick Observatory for reference.

yond a certain limit, the slight contrast between the sky and the fainter corona will inevitably be lost.*

The problem of photographing the outer corona is the same as that of photographing light clouds near the sun, or a star in the daytime; and it appears that the failure of the mirrors of the British expeditions to show more extension than the cameras could have been predicted, even for the shorter exposures, and still more for the longer ones."

THE ASTRONOMICAL SOCIETY OF CAMDEN, NEW JERSEY.

By A. B. Depuy, Secretary.

Note.—A letter from Mr. Depuy, Secretary of the Camden Astronomical Society (and also a member of the Astronomical Society of the Pacific), has lately been received, which gives an account of the organization and work of the former body. Mr. Depuy has consented to allow extracts from his letter to be printed here, as follows:

"In the fall of 1888, I was persuaded to purchase an old reflector. After setting it up in my back-yard, I invited some of my friends to call and examine it. Among them were Mr. E. E. Read Jr., our President, and Mr. Charles Bowden. Mr. Read was the possessor of a three-inch glass of French make, considered very fine, and Mr. Bowden of a four-inch, by Fitz. After seeing through my "cannon," as they were pleased to call it, Mr. Read became dissatisfied with his smaller glass, and determined to purchase a large one. It was subsequently proposed that we should form ourselves into a society,

* M. A. de la Baume Pluvinel photographed the eclipse of December from a point near Cayenne, with five cameras of different light-ratios mounted on the same stand. He says of his results (*Comptes-Rendus*, 1890, February): "Une première comparaison des cinq épreuves montre que les objectifs les plus lumineux n'ont pas donnés des images plus complètes que les objectifs les moins lumineux. L'emploi d'instruments trop puissants n'est pas même à recommander, car l'image qu'ils donnent du ciel peut être assez intense pour se confondre avec l'image des régions peu lumineuses de la couronne."

An excellent illustration of the two methods referred to may be had by employing the same camera, *first*, to photograph the earth-light on the Moon in the dark evening sky, and, *second*, to photograph the Moon itself in broad daylight. In the first case the sky has little actinic effect and the exposure may be made, consequently, quite long—several minutes, for example. (See a note on this subject by Mr. Barnard in the present number of the *Publications*.) In the second instance the quickest exposures will alone give good results. As an example, I may quote negatives made with the great telescope ($^{a}/_{f} = \frac{1}{17.8}$) on April 23, 1890, with the Moon nearly on the meridian, about 4 P.M. An exposure of one-tenth second on Seed 26 plates gave a good contrast between the limb of the moon and the sky; other negatives taken April 26th, at 2 P.M., with the aperture contracted to fifteen inches ($^{a}/_{f} = \frac{1}{45}$) and exposure of one tenth of a second on similar plates, are far more satisfactory, as the details on the moon's surface begin to show.

and that we should build and thoroughly equip an observatory for the use of the members.

On the 9th of January, 1889, we held our first meeting, with five members present. Mr. READ was elected President, and myself Secretary. We appointed committees on the observations of the sun, moon, stars, planets and nebulæ. These committees make reports (verbal) at each quarterly meeting, and a written report each year of the work done during that time.

Our instruments are as follows: The observatory, owned by Mr. READ, containing a 5½-inch refractor, mounted on an equatorial stand, with driving-clock and circles complete, by COOKE; sidereal clock; chronograph; two-inch transit; spectroscope, and electric illumination for circles. My own outfit consists of a 9½-inch reflector and photographic apparatus; Mr. BOWDEN has a four-inch refractor; Dr. R. M. LUTHER, a three-inch refractor; Professor F. P. LEAVENWORTH, at Haverford, has a ten-inch CLARK refractor; H. H. FURNESS, Jr., has a complete observatory, covering a 4½-inch refractor.

We now have fourteen members, most of whom have telescopes ranging from three to six-inch aperture.

As to our work: Mr. READ makes regular observations of the sun, noting all spots, determining their positions, and making drawings of all prominences. Mr. FURNESS is occupied with the same work. Professor LEAVENWORTH devotes himself to double-star measurements. Mr. HEWITT, one of our members living at Burlington, N. J., will shortly have mounted an excellent six-inch glass by GRUBB. I am at work on the moon, and have made about two dozen negatives, which, although very inferior, are showing signs of improvement.

In conclusion, I will say that we are all being greatly benefited by our association; and although our growth is slow, compared with that of our friends of the Astronomical Society of the Pacific, we are gradually getting in a condition to do some real work in the future."

ELEMENTS OF COMET BROOKS (MARCH 19, 1890).

BY A. O. LEUSCHNER.

From the observations, Harvard College, March 21, Lick Observatory, March 26 and 31, I have deduced the following elements of Comet Brooks (1890, March 19):

$$T = 1890, \text{ June } 2.37711 \text{ G. m. t.}$$

$$\left.\begin{aligned} \omega &= 69^\circ\ 54'\ 51''.1 \\ \Omega &= 320^\circ\ 33'\ 12''.4 \\ i &= 120^\circ\ 55'\ 57''.0 \end{aligned}\right\} \text{M. Equinox. } 1890.0$$

$$\log q = 0.276490$$

$$\text{O—C}: \Delta\lambda . \cos\beta = +4''.6;\ \Delta\beta = -2''.7$$

$$x = \overline{0.199962} \sin(182^\circ\ 50'\ 20''.6 + v) \sec^2 \tfrac{1}{2} v$$

$$y = \overline{0.237990} \sin(289^\circ\ 28'\ 30''.2 + v) \quad \text{"} \quad \text{"}$$

$$z = \overline{0.107627} \sin(\ 48^\circ\ \ 0'\ 36''.7 + v) \quad \text{"} \quad \text{"}$$

The following positions were computed from these elements:

Gr. M. T.	α	δ	*Brightness.*
April 23.5 . .	316° 31′	24° 6′	1.87
May 13.5 . .	309° 57′	40° 50′	2.76
Perihelion . .	287° 16′	59° 44′	3.33
June 22.5 . .	235° 10′	65° 4′	2.86

The unit-brightness is the brightness at the time of the first observation (Harvard College, March 21). According to this ephemeris the comet will be brightest shortly after perihelion-passage. It will not, however, become visible to the naked eye. On March 21, its distance from the sun was 143 million miles and from the earth 248 million miles. At the time of perihelion the distances will be 194 million miles from the sun and 175 million miles from the earth.

ARMIN O. LEUSCHNER.

LICK OBSERVATORY, 1890, April 7.

AWARD OF THE DONOHOE COMET MEDAL.

The comet medal has been awarded (for the first time) to Professor WILLIAM R. BROOKS, Director of the Observatory of Geneva, New York, for his discovery of a comet on March 19, 1890. This comet is the thirteenth discovered by Professor BROOKS.

TRANSLATIONS OF ARTICLES IN FOREIGN JOURNALS FOR THE *PUBLICATIONS A. S. P.*

Very frequently articles appear in foreign journals which ought to be available in the English language to our members. Members of the Society can render a great service by translating such articles for

reprinting in our *Publications*; and they can, also, in this way, materially lighten the work of the Committee on Publication. May we then suggest to any member of the A. S. P. who is willing to undertake an occasional translation from German, French or Italian into English, that he communicate with either of the undersigned, and signify his willingness, and also say which languages he is most familiar with? The articles for reprinting will be selected by the Committee (and we shall be grateful for any suggestions in the matter), and the books containing them can usually be sent to the translators.

E. S. Holden, J. E. Keeler, C. G. Yale,
Committee on Publication.

ON THE CRITERION OF CONTINUITY OF FUNCTIONS OF A REAL VARIABLE AND ON THE THEOREM OF MEAN VALUE.

By Irving Stringham, Ph. D.

The following geometrical representation presents the criterion of continuity of a function of a real variable in an interesting form, and leads to a sort of generalized theorem of mean value expressing a relation between the *incremental* and *decremental* derivatives.

The Geometrical Representation.

Let X be a point of the curve represented by the equation $y = f(x)$. (Figure 1.) Draw two parallel chords, PQ and $P'Q'$, the latter intercepting the curve at two points, P', Q', near X on either side, and suppose x to be a continuously increasing or decreasing variable within the interval PQ, assuming once only all real values between a and b, where

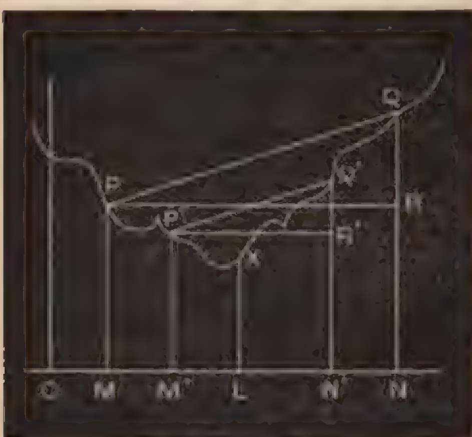

Figure 1.

$$OM = a,$$
$$ON = b = a + h,$$

so that the abscissa of

any point between P and Q will lie, in numerical value, between a and b. Complete the figure by drawing through P, P', Q, Q', etc., lines parallel to the co-ordinate axes, and let

$$MN = h, \quad ML = \theta h,$$
$$M'N' = k, \quad M'L = \epsilon k,$$

so that the values of θ and ϵ lie between 0 and + 1. Then

$$MM' = \theta h - \epsilon k, \quad OM' = a + \theta h - \epsilon k,$$
$$OL = a + \theta h, \quad ON' = a + \theta h - \epsilon k + k;$$

and by similar triangles

$$\frac{RQ}{PR} = \frac{R'Q'}{P'R'},$$

that is

$$\frac{f(a+h) - f(a)}{h} = \frac{f(a + \theta h - \epsilon k + k) - f(a + \theta h - \epsilon k)}{k},$$

with the conditions

$$1 \geqq \theta \geqq 0, \quad 1 \geqq \epsilon \geqq 0.$$

This will be referred to as the *difference equation.*

THE CRITERION OF CONTINUITY.

If the difference equation persist while ϵ varies continuously between 0 and + 1, LX, or $f(a + \theta h)$, will be a true ordinate to the curve for every value of ϵ so chosen, and the function will be continuous throughout the interval $P'Q'$; it will be discontinuous for the values of ϵ that make the difference equation impossible. Hence, the ordinate $f(a + \theta h)$ will vary continuously within the entire interval PQ, provided, independently of the value of ϵ and for every value of h between zero and MN, the ordinates $M'P'$, $N'Q'$ have a common limiting value as they approach each other,* or, what is the same thing, provided the limiting value of their difference is zero when k approaches zero. Hence the criterion of continuity for the function within the interval PQ may be stated as follows:

If for every value of ϵ *between* 0 *and* + 1 *and every value of* h *between* 0 *and* b — a, *the condition*

$$\lim_{k=0} \left\{ f(a + \theta h - \epsilon k + k) - f(a + \theta h - \epsilon k) \right\} = 0,$$
$$h \geqq k \geqq 0, \quad 1 \geqq \theta \geqq 0,$$

be satisfied, then the function f (x) *is continuous throughout the interval from* a *to* b.

* Compare Harnack, *Differential u. Integral Rechnung*, p. 25.

In particular, the function is continuous within the indefinitely small interval $P' Q'$, defined in position by the abscissa $[a + \theta h]_{k=0}$, *if for every value of* ϵ *between* 0 *and* + 1

$$\lim_{k=0} \left\{ f(a + \theta h - \epsilon k + k) - f(a + \theta h - \epsilon k) \right\} = 0,$$

$$1 \geqq \theta \geqq 0.$$

Any value of $[a + \theta h]_{k=0}$ *that permits the failure of this condition defines a point of discontinuity.*

In applying the criterion, the abscissa $a + \theta h$ will, of course, usually be an assumed and therefore a known quantity.

The Theorem of Mean Value.

In order to investigate the limiting value of the difference ratio for $k = 0$ in critical cases, it is expedient to write the difference equation in the form

$$\frac{f(a + h) - f(a)}{h} = (1 - \epsilon) \frac{f(a + \theta h - \epsilon k + k) - f(a + \theta h)}{-\epsilon k + k}$$

$$+ \epsilon \frac{f(a + \theta h - \epsilon k) - f(a + \theta h)}{-\epsilon k}.$$

This is obtained by adding $f(a + \theta h)$ to the term $-f(a + \theta h - \epsilon k)$ and subtracting it from $f(a + \theta h - \epsilon k + k)$. The coefficients of $(1 - \epsilon)$ and ϵ in this equation I call the *incremental* and *decremental* difference-ratios respectively, and the corresponding derivatives, obtained by passing to the limit for $k = 0$, I name the *incremental* and *decremental* derivatives;* for brevity, these will be referred to collectively as the two critical derivatives. In order to distinguish the derivatives from each other symbolically, the former will be denoted by $f'_+(a + \theta h)$, the latter by $f'_-(a + \theta h)$.

If in the difference equation in its revised form we are allowed to pass to the limit for $k = 0$, it becomes (since ϵ does not in general vanish with k),

$$\frac{f(a + h) - f(a)}{h} = (1 - \epsilon)\, f'_+(a + \theta h) + \epsilon\, f'_-(a + \theta h).$$

Now, so long as the function remains continuous and one-valued, k may be made, by virtue of the criterion of continuity, to pass to its limit zero, and if then the critical derivatives are determinate, the above equation exists for some value of ϵ and some value of θ, satis-

* In German "Vor- und Rückwarts-genommene Differential-quotienten." See Harnack *Differential u. Integral Rechnung*, p. 33.

fying the conditions $1 \geqq \epsilon \geqq 0$, $1 \geqq \theta \geqq 0$. This result may be stated in the following formal theorem:

If, within the interval from a *to* a + h, f (x) *be a continuous and one-valued function, and if its incremental and decremental derivatives are, throughout this interval, separately finite and determinate, then for some value of* ϵ *and for some value of* θ *satisfying the conditions*

$$1 \geqq \epsilon \geqq 0, \quad 1 \geqq \theta \geqq 0,$$

there exists a value $a + \theta h$, *of the variable, intermediate between* a *and* a + h, *such that*

$$\frac{f(a+h) - f(a)}{h} = (1 - \epsilon)\, f'_+(a + \theta h) + \epsilon\, f'_-(a + \theta h).$$

This theorem obtains for all finite determinate values of the critical derivatives, however great they may be; and since $\dfrac{f(a+h) - f(a)}{h}$ is finite by construction, if $f'_+(a + \theta h)$ approaches $\pm \infty$, either ϵ becomes unity or $f'_-(a + \theta h)$ approaches $\mp \infty$; but if $f'_-(a + \theta h)$ approaches $\pm \infty$ while $f'_+(a + \theta h)$ remains finite, then ϵ beeomes zero. Hence the following corollary:

If at a point at which the function is continuous and one-valued, one of the critical derivatives becomes $+ \infty$, *either the other becomes* $- \infty$ *or else* ϵ *is zero or unity.*

Hence, also, if the critical derivatives are equal, they are finite (may be zero); and again, if they are equal, the function being continuous and one-valued, the corresponding critical difference-ratios approach a definite limit when k approaches zero. The above theorem of mean value then takes the special form

$$\frac{f(a+h) - f(a)}{h} = f'(a + \theta h),$$

which is Rolle's Theorem.

In particular, if $f'_+(a + \theta h)$ and $f'_-(a + \theta h)$ are both zero for all values of h within the interval considered, then $f(a + h)$ remains throughout equal to $f(a)$, a constant.

These results may be briefly recapitulated as follows: The function being continuous and one-valued within the interval considered, the values of the critical derivatives and the forms of the theorem of mean value correspond in the following manner, where $f'(a, h)$ stands for $f\dfrac{(a+h) - f(a)}{h}$.

If the critical derivatives are finite and different,

$$f'(a, h) = (1-\epsilon) f'_{+}(a+\theta h) + \epsilon f'_{-}(a+\theta h).$$

If both are infinite,

$$f'(a, h) = \pm\infty \mp \infty.$$

If only one is infinite,

$$\text{either } f'(a, h) = f'_{+}(a+\theta h) \pm \lim_{k=0} \left\{ \epsilon f'(a+\theta h, -\epsilon k) \right\},$$

$$\text{or } f'(a, h) = f'_{-}(a+\theta h) \pm \lim_{k=0} \left\{ (1-\epsilon) f'(a+\theta h, -\epsilon k + k) \right\}.$$

If identical (cannot be infinite),

$$f'(a, h) = f'(a+\theta h). \quad \text{[Rolle's Theorem.]}$$

If both are zero,

$$f'(a, h) = 0, \quad f(x) = \text{constant}.$$

If only one is zero,

$$f'(a, h) = \epsilon f'_{-}(a+\theta h), \text{ or } = (1-\epsilon) f'_{+}(a+\theta h).$$

The Circle of Curvature.

Through the three points P', Q', X of Figure 1, let a circle be passed, as shown in Figure 2, and suppose the chords $P'X$, $Q'X$ to intersect the x-axis in E and F, respectively. Let

$P'Q' = g$,
angle $P'ES = \lambda$,
angle $Q'FS = \mu$,
R = radius of circle.

Figure 2.

Then

$$R = \frac{g}{2 \sin(\lambda - \mu)}.$$

If $c = a + \theta h$, the co-ordinates of P' and Q' are:

$$\text{of } P', \quad c - \epsilon k, \qquad f(c - \epsilon k),$$

$$\text{of } Q', \quad c - \epsilon k + k, \quad f(c - \epsilon k + k).$$

Hence,

$$g^2 = k^2 + [f(c - \epsilon k + k) - f(c - \epsilon k)]^2$$

$$= k^2 + k^2 \left\{ (1 - \epsilon) \frac{f(c - \epsilon k + k) - f(c)}{-\epsilon k + k} + \epsilon \frac{f(c - \epsilon k) - f(c)}{-\epsilon k} \right\}^2$$

$$= k^2 + k^2 [(1 - \epsilon) \tan \mu + \epsilon \tan \lambda]^2 ;$$

$$\therefore \mathrm{R} = \pm \frac{k}{2} \frac{\sqrt{1 + [\epsilon \tan \lambda + (1 - \epsilon) \tan \mu]^2}}{\sin (\lambda - \mu)},$$

$$= \pm \frac{k}{2} \frac{\sec \lambda \sec \mu \sqrt{1 + [\epsilon \tan \lambda + (1 - \epsilon) \tan \mu]^2}}{\tan \lambda - \tan \mu}.$$

Evidently the condition for the existence of a circle of curvature is

$$\lambda - \mu = \pm 180^\circ, \text{ when } k = 0.$$

When this condition is fulfilled, the above expression for R easily reduces to the well-known expression for radius of curvature.

BERKELEY, July, 1889.

DOES THE COLOR OF A STAR INDICATE ITS AGE?

By WILLIAM M. PIERSON.

Much discussion has been indulged in as to the relative ages of the stars, and widely divergent conclusions have resulted. ZOELLNER, in 1865, maintained that yellow and red stars are simply white stars in various stages of cooling. D'ARREST refused to adopt the theory. VOGEL, however, in 1874, classified the spectra of the stars on ZOELLNER's theory as being the "rational" basis. Father SECCHI leaned towards the same theory. Professor YOUNG indicates great doubts as to its correctness, and, in that connection, says: "But it is very far from certain that a red star is not just as likely to be younger than a white one, as to be older. It probably is now at a lower temperature, and possesses a more extensive envelope of gases, but it may be increasing in temperature as well as decreasing. At any rate, we have no certain knowledge about its age." (*Gen'l Astr.*, Sec. 858.) M. JANSSEN, Director of the Observatory at Meudon, France, has, however, maintained the same theory. An abstract of his valuable paper, read before the Institute of France, will be found in Volume 7 of the *Sidereal Messenger* (p. 202). His conclusions are that in-

asmuch as the bluish star indicates, spectroscopically, the existence of large quantities of hydrogen in its composition, it is probably the hottest, while stars more or less red, such as our sun and *Aldebaran*, where the spectrum displays the existence of large quantities of metallic vapors, have passed the stage of most active radiation. Thus the blue star, on that theory, would be the youngest, and the red star the oldest.

In the hope that further discussion of this interesting subject may not be wholly useless, I venture, with great hesitation, the following suggestions:

If we knew, approximately, the relative sizes of two stars, and also knew that the two stars had a common origin, and were, therefore, in all probability, composed of the same constituent elements, it would seem probable that the external appearance or color of the two might be an index of their relative ages, or their relative development from their common origin.

Do not the binary stars afford us these important conditions?

As we shall hereafter see, in all these binary systems, where the components are of unequal magnitude, the color of the smaller of the two stars is invariably nearer the blue end of the spectrum than that of the larger.

As to the relative size of the two components, it is evident that, whether the orbit of the binary be perpendicular to our line of sight or not, we know that the two components are, substantially, equally distant from the eye. If the apparent magnitude of one be less than that of the other, we know that it is because the one is actually smaller than the other, and not because, as in instances of double stars not binary, one may be at an enormously greater distance than the other.

As to their common origin, there are three possible theories, so far as our present scientific knowledge extends:

First—That in the proper motion, which all stars have, two suns may have come within the range of each other's attraction, and into orbital relations with each other;

Second—That two distinct nebulous masses have, in like manner, been brought into the same orbital relations, ripening afterwards into suns; and,

Third—That the two suns are the product of one nebulous mass, one part thrown off or rather left behind by the rotation of the original mass, according to the LAPLACE theory, and both thereafter

condensing into suns, and revolving around a common center of gravity.

The first theory is inadmissible, unless we are to conclude that in the journeys of the stars through space the larger star, whose light was lowest in the spectrum, always chanced to draw within its attraction a smaller one, whose light was higher. The chances of all these larger stars having made this peculiar selection of companions are so infinitesimally small as to require no discussion.

The second theory is not improbable, but as yet no such orbital movement of nebulæ has been observed, although occasionally suspected. (FLAMMARION, in *Comptes Rendus*, t. lxxxviii, p. 27.)

The third theory is not inconsistent with the generally accepted nebular hypothesis, and on it I shall base what I have to suggest on the subject.

Assuming, then, the correctness of the nebular hypothesis and that one nebulous mass had, in contracting, left behind a portion of its mass which revolved around it or about a common centre of gravity, and that both masses had condensed into suns, we have a common origin for the binary stars, and the fact that both suns are composed substantially of the same substances.

If, then, we know, on the assumptions we have made, that two stars of a given system have a common nebulous origin, and are approximately the same distance from the eye, and that, therefore, their respective magnitudes represent a difference in their actual volumes, what does observation show as to the respective colors of the two components?

I append to this paper a table of 188 undoubtedly binary stars, the details of which I have gathered from all the sources at my command, and containing every binary whose magnitudes and colors I could collect. They are arranged in the order of the difference in magnitudes of the components from those binaries whose members are equal in magnitude to those where the difference is nine and one-half entire magnitudes.

Of 130 of these systems where the companions do not differ more than one magnitude, the colors of the two are precisely similar or so nearly so as to require such peculiar nomenclature, as the characterizing of one as white, and the other pale white; one as yellow, the other yellowish; one bluish white, the other purplish white, etc. As the disparity in magnitude increases, so does the disparity in color,—the smaller of the two invariably assuming a hue nearer the blue end of the spectrum than the larger until, in the in-

stances of STRUVE, 946, *β Leporis*, *ι Ursæ Majoris* and *Sirius*, the light of the smaller is of such a peculiarly bluish tint, or else so dim, as to lead acute observers to suspect that it is not a companion sun, but has cooled down to the planetary stage. Thus, in the case of *Sirius*, OTTO STRUVE thought that the nature of the small companion must be either very different from *Sirius*, or it would, from its probable mass, shine as a first-magnitude star; while DAVIS asks, "Is it an enormously large globe endued with very small light-producing power? or perhaps shining by reflection from *Sirius?*"

The binary *ι Ursæ Majoris*, where the primary is of the 3.5 magnitude and yellow in color and the companion is of the thirteenth magnitude and purple, the light of the latter is so dim as to have led eminent astronomers to think that it may shine by reflected light, and to be therefore planetary, and BUFFHAM to remark that it is very dull for its size.

So *β Leporis*, where the primary is 3.5 magnitude and the companion of the eleventh, the larger star is yellow and the companion blue—but the latter is so dark as to also lead observers to suspect that it is planetary.

The binary STRUVE 946 is composed of a 7.5 and a tenth-magnitude star, but the smaller is again thought to have reached the planetary stage.

In other words, in all these binary systems, if the stars are of the same size, they are invariably of the same color; if, on the other hand, the magnitudes differ, the colors of the components differ in an approximately exact ratio, and where one of the members is smaller than the other, its color is invariably nearer the blue end of the spectrum than that of the larger. Thus, if the larger is red, the smaller may be yellow or white; if the larger is yellowish or white, the smaller is green, or lilac, or blue; while no binary has ever been discovered where the larger star is blue or white and its smaller companion yellow or red; or where the smaller was nearer the red end of the spectrum than its primary.

Assuming then that two stars have the same nebulous origin, are exposed to the same conditions in space, that the smaller of the two is invariably of a hue farther removed from the red end of the spectrum than the larger, the question arises—which is the older? *i. e.*, which the more developed from the original nebulous conditon,—the larger or more nearly red, or the smaller or more nearly blue?

If the bluer star be the hotter, and, therefore, the newer, or

more recently emerged from its nebulous origin, then if the binary stars are to be included in the discussion, the smaller of two bodies composed of the same elements, and having a common origin, must be the hotter. Of course, this may be so, for in all of these speculations we are dealing tentatively.

But the laws of heat and of the cooling of masses would seem to be opposed to that theory. Of two masses of matter of unequal volume, but having a common origin, and of the same original temperature, the smaller mass would cool and contract more rapidly than the larger under similar conditions. In our own solar system it is manifest that the moon has cooled more rapidly than the earth, and the smaller and terrestrial planets and asteroids than the larger ones, *Jupiter* and *Saturn*.

When in the nebular evolution the mass which now represents the planet *Jupiter* was left behind by the mass now the sun, it must have been as hot as the mass from which it separated. When, afterwards, it assumed the globular form and condensed, it was, in reality, a sun. Viewed from a point in the celestial sphere, the solar system would, undoubtedly, have then appeared as a binary system, composed of, say for illustration, stars of the second and fifteenth magnitude. But the sun *Jupiter*, under the laws relating to physics, cooled more rapidly than the sun *Sol*, and, finally, after ages of cooling, assumed its present planetary form (although still, perhaps, shining to some extent by its own light).

If, then, we are to apply to these binary systems the laws of heat and of the cooling of masses; if we are to be guided by the analogies of our own solar system, and if it be not unreasonable to assume that the same laws operate in other systems, then it would seem to follow that the smaller of two components of a binary star cannot be of a higher temperature than the larger, and, therefore, must be older in development from the nebulous stage. If that be so, then observation of the binary stars proves that the cooler the star the more its color tends toward the blue end of the spectrum. It would further seem to be a fair deduction from that conclusion that the tendency towards the blue in the color of any star, binary or independent, would indicate that the star is cooler and older, relatively, than the star whose hue tends towards the red or yellow.

TABLE OF BINARY STARS, WITH RELATIVE COLORS AND MAGNITUDES

Binaries indicated by (*) are those whose orbits have been computed.

No.	BINARY STARS.	MAGNITUDES.		Difference in Magnitudes.	COLORS.
1.	Struve, 367	8	8	0.0	Both yellowish white.
2.	Struve, 1517	7.3	7.3	0.0	Both faint yellow.
3.	42 Coma Ber.*	6	6	0.0	Both white or both yellow
4.	γ Cor. Austral.*	6	6	0.0	Both faint yellow.
5.	Struve, 2173*	6	6	0.0	Both yellow gold.
6.	Struve, 1037*	7.1	7.1	0.0	Both yellowish.
7.	ρ Eridani*	6	6	0.0	Both yellow.
8.	γ Virginis*	3	3	0.0	Both yellow.
9.	δ Equulei*	4.5	4.5	0.0	Both yellow.
10.	Struve, 186	7.2	7.2	0.0	Both white.
11.	O. Struve, 187	7.3	7.3	0.0	Both white.
12.	Struve, 1883	7	7	0.0	Both yellowish.
13.	Struve, 3091	7.7	7.7	0.0	Both yellow.
14.	Struve, 1934	8.5	8.5	0.0	Both white.
15.	Struve, 572 (4 Aurigæ)	6.5	6.5	0.0	Both yellowish.
16.	Struve, 577	7.7	7.7	0.0	Both white.
17.	Struve, 589	8	8	0.0	Whitish yellow.
18.	Struve, 619	8.7	8.7	0.0	Both white.
19.	Struve, 1093	8.2	8.2	0.0	Both white.
20.	Struve, 2267	8	8	0.0	Both white.
21.	Struve, 2799 (20 Pegasi)	6.6	6.6	0.0	Both yellowish.
22.	Struve, 2928	8	8	0.0	Both white.
23.	Otto Struve, 495	7.4	7.4	0.0	Both white.
24.	Struve, 3056	7.4	7.4	0.0	Both yellowish.
25.	Struve, 3050	6	6	0.0	Both yellowish.
26.	Struve, 1348	7.5	7.6	0.1	Both white.
27.	7 Tauri	6.6	6.7	0.1	Both white yellowish.
28.	μ Draconis*	5	5.1	0.1	White, pale white.
29.	ζ Aquarii*	4	4.1	0.1	Flushed white, creamy.
30.	Struve, 1819*	7.9	8	0.1	Both yellowish.
31.	λ Cassiopeiæ	6.0	6.1	0.1	Both white.
32.	Struve, 749	7.1	7.2	0.1	Both whitish.
33.	Struve, 932	8.2	8.3	0.1	Both white.
34.	Otto Struve, 156	6.5	6.6	0.1	Both white.
35.	Struve, 2422	7.6	7.7	0.1	Both white.

36. H. 2036 (187 Ceti)	7	7.2	0.2	Both white.
37. Otto Struve, 170..	7.1	7.3	0.2	Both white.
38. 22 Cygni........	7.4	7.6	0.2	Both yellowish.
39. ζ Cancri........	5.5	5.7	0.2	Both yellow.
40. 49 Serpentis.....	6.7	6.9	0.2	Pale white, yellowish white.
41. Struve, 1338....	7	7.2	0.2	Both white.
42. Otto Struve, 298*.	7	7.3	0.3	Both yellow.
43. ξ Scorpii*.......	4.9	5.2	0.3	Both yellowish.
44. Struve, 2........	6.3	6.6	0.3	Yellow, deeper yellow.
45. ϵ^2 Lyræ.........	4.9	5.2	0.3	Both white.
46. Struve, 3121*....	7.5	7.8	0.3	Both yellowish white.
47. Struve, 1126.....	7.2	7.5	0.3	White, ashy white.
48. Struve, 677......	7.7	8	0.3	Both white.
49. Struve, 1643.....	8.4	8.7	0.3	Both white.
50. Struve, 1647.....	7.5	7.8	0.3	Both white.
51. Struve, 1785.....	7.2	7.5	0.3	Both white.
52. Struve, 1820.....	8.2	8.5	0.3	Both yellowish.
53. Struve, 1863.....	7.1	7.4	0.3	Both yellowish.
54. ε Arietis........	5.7	6	0.3	Both white.
55. Otto Struve, 234*.	7	7.4	0.4	Both white.
56. Struve, 1781.....	7.8	8.2	0.4	Both yellowish white.
57. Otto Struve, 261..	6.3	6.7	0.4	Both white.
58. ζ Boötis.........	3.5	3.9	0.4	Both white.
59. Struve, 1074.....	7.8	8.2	0.4	Both white.
60. Struve, 2847.....	7.6	8	0.4	Both yellowish.
61. η Coronæ Bor.*..	5.2	5.7	0.5	Both yellow.
62. α Geminorum*....	3	3.5	0.5	Bright white, pale white.
63. Struve, 1876.....	8.1	8.6	0.5	Both yellowish.
64. Struve, 13.......	6.6	7.1	0.5	Both yellowish.
65. ζ Sagittarii*.....	3.5	4	0.5	Colors not found.
66. P xxii...........	6	6.5	0.5	Both white.
67. Struve, 3046.....	8	8.5	0.5	Both yellowish white.
68. Struve, 3006.....	8.5	9	0.5	Both white.
69. σ Coronæ*......	8.6	9.1	0.5	Both white.
70. Struve, 266......	7.5	8	0.5	Both white.
71. Struve, 1932.....	5.6	6.1	0.5	Both white.
72. Struve, 1937.....	5.2	5.7	0.5	Both yellow.
73. Struve, 257......	7.2	7.7	0.5	Both yellowish white.
74. Otto Struve, 52...	6.2	6.7	0.5	Both white.
75. Struve, 511......	7.5	8	0.5	Both white.
76. 20 Draconis.....	6.4	6.9	0.5	Both white.

77.	Struve, 2384....	8	8.5	0.5	Both yellow.
78.	Struve, 2556....	7.3	7.8	0.5	Both white.
79.	ε Equulei	5.7	6.2	0.5	Both yellowish.
80.	Struve, 2026 ..	8.6	9.1	0.5	Both yellow.
81.	Struve, 1500....	7.6	8.2	0.6	Both yellowish.
82.	Struve, 1944 .	7.5	8.1	0.6	Both white.
83.	Struve, 2199	7.2	7.8	0.6	Both yellowish.
84.	Struve, 2438...	7	7.6	0.6	Both white.
85.	Struve, 742.....	7.2	7.8	0.6	Yellowish, white.
86.	φ Ursæ Majoris*	5	5.6	0.6	Colors not found.
87.	μ Boötis*	6.7	7.3	0.6	Both greenish white.
88.	61 Cygni*......	5.3	5.9	0.6	Yellow, deeper yellow.
89.	τ Ophiuchi* .	5	5.7	0.7	Both yellowish white.
90.	Struve, 73......	6.2	6.9	0.7	Both golden.
91.	Struve, 1216...	7.5	8.2	0.7	Both white.
92.	8 Sextantis....	8.6	9.3	0.7	Both yellowish.
93.	Otto Struve, 224.	7.3	8	0.7	Colors not found.
94.	Struve, 1734 .	7.2	7.9	0.7	Both white.
95.	Struve, 910.....	8.3	9	0.7	Both yellowish.
96.	Struve, 1081....	7.8	8.5	0.7	Both white.
97.	Struve, 2744....	6.3	7	0.7	Both white.
98.	Struve, 2804....	7.3	8	0.7	Both white.
99.	Struve, 1356.. .	6.2	7	0.8	Both yellow.
100.	Struve, 1476....	7.2	8	0.8	Both white.
101.	Otto Struve, 215.	6.5	7.3	0.8	White, ashy white.
102.	14 (ι) Orionis* ..	6	6.8	0.8	Both white.
103.	ω Leonis*......	6.2	7	0.8	Yellow, yellower.
104.	Struve, 945.....	7.1	8	0.9	Both white.
105.	ξ Ursæ Majoris*.	4	4.9	0.9	White, grayish white.
106.	Struve, 228.....	6.7	7.6	0.9	Both white.
107.	12 Lyncis......	5.2	6.1	0.9	Both yellowish white.
108.	Struve, 1187....	7.1	8	0.9	Both white.
109.	Struve, 234.....	7.8	8.7	0.9	Both white.
110.	Struve, 305.....	7.3	8.2	0.9	Both yellow.
111.	Struve, 1457....	7.4	8.4	1.0	Both yellowish white.
112.	Struve, 1808....	8	9	1.0	Both white.
113.	66 Piscium.....	6.2	7.2	1.0	Both white.
114.	42 Ceti........	6.2	7.2	1.0	Both white.
115.	Struve, 676.....	7.5	8.5	1.0	Both white.
116.	Struve, 2315. .	7	8	1.0	Both white.
117.	Struve, 2822....	4	5	1.0	White, whitish blue.

truve, 1989 . .	7.1	8.1	1.0	Both white.
truve, 2934	8.2	9.2	1.0	Whitish yellow, white.
truve, 941 . . .	7	[illegible]	1.0	Bluish white, purplish white.
² Herculis*	9.5	10.5	1.0	Both white.
Serpentis	3	4	1.0	Yellow, ashy yellow.
Centauri	1	2	1.0	Both yellowish or reddish.
6 Andromedæ*	6	7	1.0	Bright orange, yellow.
tto Struve, 400*	7.2	8.2	1.0	Colors not found.
truve, 3062* . . .	6.9	8	1.1	Yellowish white, bluish.
truve, 1757* . . .	7.8	8.9	1.1	Pale white, yellowish.
truve, 2509	7	8.1	1.1	Both yellowish.
truve, 2289	6	7.1	1.1	Both bluish.
truve, 2114	6.2	7.4	1.2	Both white.
truve, 963	5.9	7.1	1.2	Golden, purplish.
truve, 1639	6.7	7.9	1.2	White, ashy.
tto Struve, 338 .	6.5	7.7	1.2	Both yellow.
truve, 1374	7	8.3	1.3	Yellowish, sky blue.
7 Pegasi	5.8	7.2	1.4	Both white.
tto Struve	6.3	7.7	1.4	White, ashy olive.
Leonis*	2	3.5	1.5	White, gray green.
truve, 2107* . . .	6.5	8	1.5	Yellowish, bluish.
2 Orionis	5.2	6.7	1.5	Both yellowish.
truve, 2281 . . .	5.7	7.2	1.5	Both white.
truve, 535	6.7	8.2	1.5	Yellowish, bluish.
truve, 1104 . .	6.7	8.3	1.6	Both white.
tto Struve, 296	7	8.6	1.6	Colors not found.
Andromedæ . . .	4.9	6.5	1.6	Yellow, green.
truve, 1837	7.1	8.7	1.6	Pale yellow, greenish.
truve, 2106	6.7	8.4	1.7	Both white.
Boötis*	4.7	6.6	1.9	Deep yellow, flushed purple.
Andromedæ . . .	3.5	5.5	2.0	Deep yellow, sea green.
truve, 208	6.5	8.5	2.0	Yellow, pale gray.
Aquarii*	4.5	6.5	2.0	Pale yellow, purple.
Cephei	5	7	2.0	Yellowish, bluish.
o (o²) Eridani* .	9	11	2.0	Orange, sky blue.
Ophiuchi* . .	4.1	6.1	2.0	Topaz, purplish.
tto Struve, 483 .	6	[illegible]	2.0	White, ashy.
tto Struve, 413 .	5.5	7.6	2.1	White, ashy.
Ophiuchi	4	6.1	2.1	Yellowish, bluish.
truve, 422	6	8.2	2.2	Yellow, blue.
Lyræ	4	6.3	2.3	Yellowish, bluish.

159.	2 Camelopardali	5.1	7.4	2.3	Yellow, bluish.
160.	π Cephei*	5.2	7.5	2.3	Yellow, purple.
161.	τ Cygni	5.6	7.9	2.3	Yellow, blue.
162.	β Cygni	3	5.3	2.3	Gold yellow, smalt blue.
163.	38 Geminorum	5.4	7.7	2.3	Light yellow, purple.
164.	ο Virginis	5.8	8.2	2.4	Yellowish, smalt blue.
165.	Struve, 946	7.5	10	2.5	White, blue. Companion suspected to be planetary.
166.	Otto Struve, 159	4.7	7.2	2.5	Yellow, bluish.
167.	ο Cephei	5.2	7.8	2.6	Yellow, very blue.
168.	25 Can. Venat.*	5	7.6	2.6	White, blue.
169.	35 Comæ Bor.	5	7.8	2.8	Yellowish, blue.
170.	ι Cassiopeiæ	4.2	7.1	2.9	Yellow, blue.
171.	γ Cor. Boreal.*	4	7	3.0	Greenish white, purple.
172.	Struve, 489	4.4	7.5	3.1	Yellow, Olive green.
173.	ι Leonis	4.8	7.9	3.1	Yellowish, blue.
174.	ο² Ursæ Majoris	5	8.2	3.2	Flushed white, sapphire blue.
175.	Struve, 295	6	9.2	3.2	Yellow, ashy.
176.	ε Boötis	3	6.3	3.3	Reddish, bluish.
177.	η Cassiopeiæ*	4	7.6	3.6	Yellowish white, purple.
178.	ε Draconis	4	7.6	3.6	Light yellow, blue.
179.	γ Ceti	3	6.8	3.8	Pale yellow, lucid blue.
180.	84 Ceti	6	10	4.0	Yellow, blue.
181.	ε Hydræ	3.8	7.8	4.0	Pale yellow, purple.
182.	δ Cygni*	3	7.9	4.9	Pale yellow, greenish blue.
183.	Struve, 1066	3.2	8.2	5.0	Yellowish, purplish.
184.	α Scorpii (Antares)	1	7	6.0	Red, green.
185.	β Leporis	3.5	11	7.5	Deep yellow; companion blue. Companion suspected to be a planet.
186.	β Delphini*	4	12 & 15	8.0	Triple; primary greenish, companions dusky.
187.	α Canis Majoris (Sirius)*	1	10	9.0	Primary white; companion dim. Companion suspected to be a planet.
188.	ι Ursæ Majoris	3.5	13	9.5	Primary deep yellow; companion blue. Companion suspected to be a planet.

NOTE.—The foregoing table is compiled from the list of binary stars appended to Professor HOLDEN'S paper on the colors of binaries in the *American Journal of Science*, vol. XIX, p. 467; the list in Mr. GORE'S appendix to Professor BURNHAM'S article on Double Stars in "Astronomy for Amateurs"; Professor YOUNG'S table in his "General Astronomy"; and from WEBB'S "Celestial Objects."

NOTE ON THE DEFINITION, THE RESOLVING POWER AND THE ACCURACY OF TELESCOPES AND MICROSCOPES.

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[The following note is reprinted (with a correction) from the *American Journal of Science* for February, 1890.]

Let us take the following nomenclature:

B = diameter of objective.
F = focal length of objective.
α = apparent semi-diameter of objective viewed from the object.
β = apparent semi-diameter of objective viewed from the image.
d = smallest distance between lines which can be clearly "resolved."
λ = wave-length of the light employed.
b = breadth of the diffraction fringes with this kind of light.
M = Magnification.
R = Resolution.
D = Definition.
A = Accuracy.

Then if M is the ratio of size of image to object,

$$M = \frac{\sin \alpha}{\sin \beta}$$

The *resolution* is measured by the closeness of two lines which can be clearly distinguished or "resolved." Let us therefore put

$$R = \frac{1}{d}$$

Now two lines are clearly distinguishable when the central fringes of their images are separated by the width of one fringe. The actual limit at which the resolution disappears may be anywhere between b and $\frac{b}{2}$. (See "Wave Theory," Lord RAYLEIGH, *Enc. Brit.*) But it can readily be shown that $b = \frac{\lambda}{2 \sin \beta}$ and $d = b/M$; hence,

$$R = \frac{2}{\lambda} \sin \alpha.$$

The *definition* of an objective is measured by the ease with which the forms of minute objects may be recognized. Thus, were it not for diffraction, D would be simply proportional to M. But for a given

magnification the form of the image is clearer, or the definition greater as the fringes are narrower; hence, we may put

$$D = \frac{M}{b} = R$$

Definition is not capable of being so precisely formulated as Resolution, and would undoubtedly vary with the form of the object, its nearness to other objects, etc. In view of these uncertainties, it would scarcely be worth while to introduce a constant coefficient in the last equation.

The error of setting of the cross-hairs of an eye-piece on the middle of a diffraction band of sufficient width will be b/e where e is a constant not far from 100, and the corresponding error in distance would be $b/e \div M$. This smallest *measurable* distance is therefore e times as small as the smallest *resolvable* distance; hence,

$$A = eR.$$

These formulæ may be applied to the microscope (in which case the maximum values correspond to $\alpha = 90°$), or to the telescope (in which α is nearly zero, and angular measurements alone are of importance). Accordingly we obtain the following:

	Microscope.	Telescope.
M	$= 1/\sin\beta$	F
R	$= 2/\lambda$	B/λ
D	$= 2/\lambda$	B/λ
A	$= e2/\lambda$	eB/λ

The formulæ for microscopes apply when the object is very near the lens. They show, first, that with a microscope of given length the magnifying power depends on the smallness of the objective, and on nothing else; second, that the resolution, definition and accuracy (upon which the usefulness of a microscope chiefly depends) are the same for all microscopes, no matter how large the objective may be, or how great the magnifying power, provided the latter be sufficient to show diffraction fringes; third, that these qualities vary inversely with the wave-length of the light employed.

There seems to be a prevailing impression that a microscope may have a high resolving power with but moderate definition, and *vice versa*. This may be due to the difficulty in giving an exact signification to the terms. If those here employed be admitted it is evident that the two qualities must go together.

In the telescope the size of the image and hence the magnification depends entirely on the focal length. The resolution is in this

case the reciprocal of the smallest angular distance which can be clearly distinguished. It increases with the diameter of the objective and inversely with the wave-length. These formulæ may also be applied to the revolving mirror as used in galvanometers, etc., except that in this case the accuracy is doubled, so that

$$A = 2eB/\lambda.$$

The foregoing statements must be understood to refer to theoretically perfect lenses. If the lenses be imperfect the ratio of their performance to that of a perfect lens may be expressed by a constant depending on the accuracy of the surfaces and the nature of the glass.

NOTICES FROM THE LICK OBSERVATORY.

Prepared by Members of the Staff.

Indexes to Scientific Periodicals.

An index to the volumes of the *Vierteljahrsschrift der Astronomischen Gesellschaft* from Volume I (1866) to Volume XXV (1890) is now in course of preparation, and it will supply a real want.

An index to the *Memorie della Società Spettroscopisti Italiani* is very much needed from its Volume I (1872) onwards. It is possible that some of our members who are familiar with Italian might be willing to charge themselves with this useful work, and I have no doubt that the editor (Professor Tacchini) would welcome such assistance. If any of our members are willing to undertake any such pieces of work, I shall be pleased to aid them in any way in my power. The example of the *American Journal of Science*, which prints a complete index every ten years, is an excellent one to follow. If such a thing as uniformity in this matter were to be hoped for at all, it would not be difficult to propose a general plan for indexing scientific journals which might meet with approval. My own idea would be to provide each separate volume with its index, as at present, and to print a general index to preceding volumes every even decade; —in the volumes for 1880, 1890, 1900, 1910, etc.

In the library of the United States Naval Observatory at Washington, and in the library of the Lick Observatory I introduced the plan of distinguishing every such "Index-Volume" with a special mark on its back, so that a long series, like that of the Paris Academy of Sciences, for example (1666–1890), can be quickly examined. This very simple device saves much time and annoyance, and is worth the attention of librarians. E. S. H.

Index to the Uranometries of Argelander, Heis and Gould.

No one can use the Uranometries of Argelander and Gould without wishing for an alphabetical index to the constellations which shall give the page where each one is to be found. I have long used such an index, which is printed below, and I am sure that it has saved me much time and no little annoyance. It is advisable to copy it into each work, once for all. Heis and Behrmann have been careful to provide an index to their Uranometries (on the last

pages). Other works of this class are so infrequently used that it is not worth while to make a special index to them. E. S. H.

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Carina	..	..	140
Cassiopea	2	15	..
Centaurus	105	150	150
Cepheus	11	9	..
Cetus	85	112	209
Chamæleon	..	..	134
Circinus	..	..	145
Columba	92	131	183
Coma Berenices	69	84	..
Cor Caroli	..	..	..
Corona austrina	115	..	178
Corona borealis	30	91	..
Corvus	104	149	213
Crater	100	148	213
Crux	..	..	155
Cygnus	38	102	..
Delphinus	80	111	231
Dorado	..	..	146
Draco	7	2	..
Equuleus	80	46	232

Constellation.	Argelander.	Heis.	Gould.
Eridanus	88	117	159
Fornax	..	..	186
Gemini	60	70	..
Grus	..	..	163
Hercules	31	92	233
Horologium	..	..	148
Hydra	98	136	191
Hydrus	..	..	133
Indus	..	..	137
Lacerta	43	27	..
Leo	64	78	229
Leo minor	67	83	..
Lepus	91	130	204
Libra	105	161	201
Lupus	106	163	168
Lynx	19	29	..
Lyra	36	99	..
Mensa	..	..	132
Microscopium	..	..	182
Monoceros	92	126	224
Musca	..	..	144
Norma	..	..	156
Octans	..	..	131
Ophiuchus	72	153	198
Orion	56	122	222
Pavo	..	..	135
Pegasus	81	47	232
Perseus	14	19	..
Phœnix	..	..	157
Pictor	..	..	149
Pisces	47	52	227
Piscis austrinus	115	174	189
Pyxis nautica	..	..	190
Puppis	..	..	170
Reticulum	..	..	149
Sagitta	79	110	..
Sagittarius	108	165	178
Scorpius	106	163	175
Sculptor	..	..	184
Scutum Sobiesii	110	157	219
Serpens	70	151	217

Constellation.	Argelander.	Heis.	Gould.
Sextans	68	141	226
Taurus	52	64	230
Telescopium	..	..	162
Triangulum	50	56	..
Triangulum australe	..	..	145
Tucana	..	..	138
Ursa major	21	32	..
Ursa minor	1	1	..
Vela	..	..	165
Virgo	101	142	214
Volans	..	..	139
Vulpecula	78	108	..

INDEX TO CHACORNAC'S CHARTS (INCLUDING ALL THE LATER PARIS CHARTS AT PRESENT AVAILABLE AT THE L. O.).

No.	R. A.		Declination.	
	h. m.	h. m.	° ′	° ′
1	0 0 to	0 20	+ 1 0 to	— 4 15
1 *a*	0 0	0 20	+ 1 0	+ 6 15
2	0 20	0 40	— 1 45	+ 3 30
2 *bis*	0 20	0 40	+ 3 30	+ 8 45
3	0 40	0 60	+ 6 15	+ 5 30
3 *a*	0 40	1 0	+ 6 30	+ 10 45
4	1 0	1 20	+ 4 45	+ 10 0
5	1 20	1 40	+ 7 0	+ 12 15
6	1 40	2 0	+ 9 0	+ 14 15
7	2 0	2 20	+ 10 30	+ 15 45
8	2 20	2 40	+ 12 15	+ 17 30
9	2 40	3 0	+ 14 0	+ 19 15
10	3 0	3 20	+ 15 15	+ 20 30
10 *a*	3 0	3 20	+ 10 0	+ 15 15
13	4 0	4 20	+ 18 45	+ 24 0
15	4 40	5 0	+ 20 0	+ 25 15
22	7 0	7 20	+ 20 0	+ 25 15
26	8 20	8 40	+ 16 15	+ 21 30
27	8 40	9 0	+ 15 0	+ 20 15

28	9 0	9 20	+ 13 45	+ 19 0
29	9 20	9 40	+ 12 15	+ 17 30
29*a*	9 20	9 40	+ 7 0	+ 12 15
30	9 40	10 0	+ 10 30	+ 15 45
31	10 0	10 20	+ 8 45	+ 14 0
32	10 20	10 40	+ 6 45	+ 12 0
33	10 40	11 0	+ 4 45	+ 10 0
34	11 0	11 20	+ 2 45	+ 8 0
35	11 20	11 40	+ 0 30	+ 5 45
36	11 40	12 0	— 1 30	+ 3 45
38	12 20	12 40	— 5 45	— 0 30
39	12 40	13 0	— 8 0	— 2 45
39	13 0	13 20	— 10 30	— 5 15
41	13 20	13 40	— 12 0	— 6 45
43	14 0	14 20	— 15 45	— 10 30
43*a*	14 0	14 20	— 10 30	— 5 15
46	15 0	15 20	— 20 30	— 15 15
48	15 40	16 0	— 22 45	— 17 30
49	16 0	16 20	— 23 45	— 18 30
50	16 20	16 40	— 24 30	— 19 15
51	16 40	17 0	— 25 0	— 19 45
52	17 0	17 20	— 25 30	— 20 15
59	19 20	19 40	— 24 30	— 19 15
60	19 40	20 0	— 23 45	— 18 30
61	20 0	20 20	— 22 45	— 17 30
62	20 20	20 40	— 21 30	— 16 15
63	20 40	21 0	— 20 15	— 15 0
64	21 0	21 20	— 22 0	— 16 45
64*a*	21 0	21 20	— 16 45	— 11 30
67	22 0	22 20	— 14 0	— 8 45
68	22 20	22 40	— 12 15	— 7 0
69	22 40	23 0	— 10 0	— 4 45
70	23 0	23 20	— 8 0	— 2 45
71	23 20	23 40	— 5 45	— 0 30
72	23 40	24 0	— 3 45	+ 1 30

INDEX TO PETERS' CHARTS, 1–20.

No.	R. A.		Declination.	
	h. m.	h. m.	°	°
1	10 0 to	10 20	+ 15 to	+ 10
2	10 20	10 40	+ 15	+ 10
3	1 0	1 20	+ 15	+ 10
4	1 0	1 20	+ 5	+ 0
5	3 0	3 20	+ 20	+ 15
6	21 0	21 20	— 20	— 25
7	21 20	21 40	— 15	— 20
8	21 20	21 40	— 10	— 15
9	21 40	22 0	— 10	— 15
10	22 0	22 20	— 5	— 10
11	10 40	11 0	+ 15	+ 10
12	11 40	12 0	+ 10	+ 5
13	12 0	12 20	+ 10	+ 5
14	11 0	11 20	0	— 5
15	12 0	12 20	0	— 5
16	12 20	12 40	0	— 5
17	14 0	14 20	— 10	— 15
18	21 40	22 0	— 15	— 20
19	22 40	23 0	— 5	— 10
20	22 20	22 40	— 5	— 10

INDEX TO PALISA'S CHARTS, 1–4.

No.	R. A.		Declination.	
	h. m.	h. m.	° ′	° ′
1	22 00 to	22 20	— 9 00 to	— 14 00
2	10 00	10 21	+ 9 00	+ 14 00
3	12 20	12 41	— 0 30	+ 4 45
4	9 40	10 00	+ 15 00	+ 20 00

Medal of the Great Comet of 1680.

I have in my possession a silver medal of the great comet of 1680, and by the courtesy of Henry Holt & Co., of New York, I am enabled to print a cut of it here. The medal was struck in the Low Countries, at some (unknown) monastery, probably while the comet was still visible, and it was distributed as a kind of amulet or charm against its evil effects. So far as I know, this medal and a companion-piece of the same design, and of about half the size (of the same time and place) are the only ones ever struck to commemorate an astronomical event (except, of course, medals distributed by scientific societies).

This great comet was discovered November 30, 1680, by Kirch, and was observed until March 18, 1681. It will be noticed that the *obverse* bears two dates—Anno 1680, 16 December, and 1681, January. If I should hazard a guess as to these dates, I should assume December 16 to be the date when the comet was first seen at the monastery, and that the medal was struck in January, 1681. The *first* observation of Hevelius, in Dantzig, is dated December 2d, and it might well be that the comet was not seen at a particular place till the 16th.

At this time the comet was in the constellations *Aquila*, *Sagitta* and *Cygnus*. I find that I cannot accurately identify all the stars as laid down. The *reverse* side of the medal is taken up with an inscription which is at once rhythmic in form and consolatory in effect. A free translation is:

This Star threatens Evil Things: but Trust!
God will turn these to Good.

This inscription contains also the year of the comet, implicitly. Collecting those letters which are written large, we have:

M	=	1000
D	=	500
C	=	100
L	=	50
VVVVVV	=	30
I	=	1
Total,		1681


UNIVERSELLE
EXPOSITION
1889

The mental image which we may form of the monkish artist, with his rhyming motto, his logogriph of 1681, his erroneous design of the star groups made indoors while the constellations were shining outside, may serve to recall to us something of the spirit of a time only two centuries ago. It must be remembered, too, that it was for this very comet of 1680 that Sir ISAAC NEWTON computed an orbit by his new methods, which showed that it revolved about the sun in a conic section, peacefully obedient to the law of gravitation. This medal, then, seems to mark a distinct division between two epochs in the history of astronomy (and in the history of human belief), and, therefore, to have a value quite apart from and above its numismatic rarity. E. S. H.

AWARD TO THE LICK OBSERVATORY AT THE PARIS EXPOSITION.

The Lick Observatory exhibited at the Paris Exposition a frame of photographic views of Mount Hamilton and some photographs of the moon taken with the great telescope. The negatives were made by Messrs. BURNHAM and BARNARD, and the smaller prints were also by them. The enlargements from these negatives were made by Mr. TABER of San Francisco. A gold medal was awarded to the Observatory for the whole exhibit. E. S. H.

"WEIGHING A DOUBLE STAR."

"In Professor E. C. PICKERING'S third Annual Report of the DRAPER Memorial work, a very interesting fact is noted in connection with the spectrum of ζ *Ursæ Majoris*, of which more than seventy photographs have been taken. It has been found that the *K* line appears doubled at intervals of fifty-two days, beginning from March 27, 1887, and that for several days before and after the dates on which it appears doubled the line presents a hazy appearance. The other lines in the spectrum are much fainter, and, although well-shown when the *K* line is clearly defined, are seen with difficulty when it is hazy. Several of them are certainly double when the *K* line is double. * * * * * * *

As Professor PICKERING remarks, the only satisfactory explanation of this phenomenon is that the brighter component of this star must be a double star, having components nearly equal in brightness and too close to have been separated as yet visually, and that the time of revolution of the system is 104 days. When one component is approaching the earth, all the lines in its spectrum will be moved towards the blue, while all the lines in the spectrum of the other

component will be moved in the opposite direction. When the motion becomes perpendicular to the line of sight, the lines recover their true wave-length and become single.

"The relative velocity as derived from one set of measures comes out as ninety-four miles a second, and as one hundred and two miles per second from another set. If the orbit is circular, and its plane passes through the sun, the distance traveled by one component in fifty-two days, regarding the other as fixed, would be about nine hundred million miles; and the distance apart of the two components would be one hundred and forty-three million miles, or about equal to that of *Mars* from the sun. The combined mass of the two must be about forty times that of the sun, to give the required period; and if the orbit is inclined to the line of sight, the dimensions of the orbit and the corresponding masses must be greater.

"In a later postscript, written on January 11th, Professor PICKERING says that the period of ζ *Ursæ Majoris* appears to be fifty-two days, instead of one hundred and four, and that its orbit is noticeably elliptical.

"A similar phenomenon has also been observed with regard to the spectrum of β *Aurigæ*. The velocity of its components seems to be one hundred and fifty miles per second, and their period four days; their orbit nearly circular. If its plane passes through the sun, it must have a radius of eight million miles, and their joint masses must be about one-fifth of the mass of the sun."—*From Knowledge for March, 1890.*

COMET OBSERVATIONS AT MOUNT HAMILTON.

From a summary of the comet observations made all over the world, during part of 1888 and all of 1889, which is given in the *Vierteljahrsschrift der Astronomische Gesellschaft* (1890, page 70), the following is condensed:

Comet 1887 V = OLBERS' comet was observed at Mt. Hamilton by Mr. BARNARD until July 5, 1888. His last observations were three months later than those at any other Observatory.

Comet 1888 IV = FAYE'S comet was observed at the Lick Observatory four days after the last European observation (Vienna).

Comet 1888 V: The last observation was made at the Lick Observatory.

Comet 1889 I was discovered at the Lick Observatory by Mr. BARNARD, on September 2, 1888. This comet is remarkable for

the long duration of its visibility. It was last observed at Mt. Hamilton on May 15, 1890, about twenty-one months after discovery. No other comet has had a longer period of visibility. The Great Comet of 1811, was visible for sixteen months and twenty days only.

Comet BROOKS, 1889, January 14 (?). This comet was discovered by BROOKS on January 14. It was never seen after that date either by its discoverer or by other observers. At Mt. Hamilton it was very carefully sought for, both by Mr. BARNARD and by Professor SWIFT, who was here on a visit.

Comet 1889 II was discovered by Mr. BARNARD 1889, March 31. The last observation at Mt. Hamilton was made on November 16, after which time severe storms set in. The last observation was made at Vienna on November 21.

Comet 1889 III was discovered by Mr. BARNARD, 1889, June 23. It moves in an elliptic orbit, with a period (according to Dr. BERBERICH) of 128.3 years. It was last observed at Mt. Hamilton, August 6.

Comet 1889 IV was discovered by Mr. DAVIDSON, in Queensland, July 19. It was photographed at the Lick Observatory by Mr. BARNARD, and its photographic brightness was determined (see *Publ.* A. S. P., vol. I, p. 34), as well as its spectrum (*loc. cit.*, p. 36). The last observation was made (November 21) at Vienna.

Comet 1889 V was discovered by BROOKS 1889, July 6. It moves in an elliptic orbit, with a period of seven years. On August 1 the comet was found to consist not only of one body, but of a family of comets moving together in space. This discovery was made by Mr. BARNARD, and has been described in *Publ.* A. S. P., vol. I, p. 72. The companion comets were observed by him until November 25. The last observation of the main comet was made at Mt. Hamilton March 20, a month later than at any other observatory. Still another interesting feature is presented by this comet in the similarity of its elements to those of LEXELL's lost comet, as pointed out by Mr. CHANDLER and described in *Publ.* A. S. P., vol. II, p. 21.

Comet 1889 VI was discovered by Professor SWIFT, at Rochester, on November 16. Its orbit is elliptic with a period of seven or eight years. The last observation was made at Mt. Hamilton on January 21, 1890.

Comet 1890 — was discovered by M. BORELLY, at Marseilles, on December 12. This is the first comet discovered in Europe since 1886.

The foregoing summary shows that the excellent atmosphere at Mt. Hamilton has made it possible for the Lick Observatory to render material services to cometary astronomy by following faint comets as long as they are visible at all, thus making greater arcs available in the calculation of their definitive orbits. E. S. H.

New Instruments for the Lick Observatory.

The Board of Directors of the Bache Fund of the National Academy of Sciences has loaned to the Lick Observatory a spectroscope specially designed for the observation of faint objects, as the Aurora and the Zodiacal Light. It will be used here to examine the spectrum of the latter object.——The Trustees of the Thompson Fund of the American Association for the Advancement of Science have made a grant of money for the construction of a small spectroscope to be used in connection with the great telescope in the observation of variable stars. The thanks of the Observatory are returned for these material additions to our spectroscopic equipment.——Hon. C. F. Crocker has authorized the construction of an equatorial stand to take the Willard photographic telescope bought by him for the observation of the eclipse of December, 1889. The mounting will be made by Mr. Brashear, and will be provided with a driving-clock, controlled in the manner invented by Mr. Keeler. The Willard lens, together with a 5½-inch Dallmeyer camera (lent to us by Mr. Pierson), will be mounted side by side, for the present, and will be employed by Mr. Barnard in making photographs of the Milky Way.——The large periscopic eye-piece made by the Gundlach Optical Company has been received. Its glasses are made from the new Jena material. The field-lens is of crown, and is six inches in diameter. The rays from this pass through a triple eye-lens, three inches in aperture. The whole length of the eye-piece is ten inches, and it weighs about thirteen pounds. The field of view is over thirty minutes. The equivalent focal distance is five inches, and, therefore, its magnifying power on the great telescope (focus 694.4 inches) is about 140 diameters. It will not utilize the whole area of the objective, consequently. It gives admirable views of the larger nebulæ, the moon, etc., as the field is flat and the color-correction is excellent.——A self-registering thermometer, made by Richard Frères of Paris, has been purchased for trial. The instrument runs a week at one winding, and appears to be very satisfactory. Its cost is but 135 francs in Paris. ——An improvement to an old instrument is often more import-

ant than the addition of a totally new one. Through the kindness of Professor T. C. MENDENHALL, Chief of the United States Coast and Geodetic Survey, a very important addition has been made to the measuring engine of the Lick Observatory by the determination of the errors of its glass scale A. This scale has 300 divisions, about 0.02 inches apart. Mr. O. H. TITTMAN, together with Messrs. PARSONS and FISCHER of the Survey, have investigated this scale,

SELF-REGISTERING THERMOMETER.

and have determined the errors of each one of the 300 divisions to the nearest 0.00001 inch. The scale thus becomes available for the examination of micrometer screws, etc., and particularly for the measures of stellar photographs taken with the large telescope where $1' = 0.1658$ inches, $1'' = 0.00276$ inches, etc. In order that the benefit of this work of the Coast Survey shall be as widely spread as possible, the Lick Observatory offers to determine the errors of scales not longer than four or five inches belonging to institutions in California, provided such scales are to be used for strictly scientific purposes.
E. S. H.

A recent addition to the original spectroscopic apparatus of the Lick Observatory is a short-focus observing telescope for the large star spectroscope by Mr. BRASHEAR. It is used with the same micrometer and other accessories that serve for the larger telescope, and is more convenient for ordinary work. The objective and a new collimator-objective of 1½ inches aperture and 20 inches focus, are made of Jena glass, cemented with Canada balsam to diminish loss of light by reflection. As small lenses made of Jena glass can now be readily obtained, it seems worth while to point out the great advantages they possess over ordinary objectives for spectroscopic work. With

ordinary objectives, if it is desired to measure the angular distance between two lines in parts of the spectrum which differ greatly in color, the focus must be adjusted for each line, otherwise the observation will be affected by error of parallax; but the adjustment of focus introduces another source of error in the irregularities of the eye-piece slide, and moreover, if the light is to pass through the prism in parallel rays, the change of focus must be divided between the observing telescope and the collimator. (In certain special forms of apparatus this is effected automatically.) With objectives properly made of Jena glass, however, the chromatic aberration is so small that all except the extreme parts of the spectrum have practically the same focus, and no adjustment is required, an advantage which adds greatly to the convenience as well as to the accuracy of the observations. The superiority of Jena glass objectives for usual telescopic work has been pointed out by Dr. Hastings, and for spectroscopic work the advantages are even more manifest. The images of bright objects with such a telescope are nearly free from false color, resembling the images formed by a reflector, and have almost an abnormal appearance to an eye accustomed to the ordinary form of refractor.

J. E. K.

Observatory for Napa College.

The Trustees of Napa College have determined to erect an observatory for the use of the students and for general purposes, and intend to purchase a refractor of seven or eight inches aperture shortly.

Post-office at Mount Hamilton.

A post-office has been established at Mount Hamilton, and Mr. S. W. Burnham (in addition to his more strictly astronomical honors) has been appointed to be United States Postmaster. It is requested that in future all letters and parcels sent by mail should be addressed to "The Lick Observatory, Mount Hamilton, California, U. S. A." Money orders should be made payable at the post-office of San José. Telegrams from points in the United States should also be addressed to San José. Cable telegrams, however, should be sent to "Astronomer, San Francisco." Parcels from abroad may be dispatched through the agents of the Smithsonian Institution (free of cost).

E. S. H.

Occultation of *Mars* by the Moon, 1890, April 8.

On the morning of Wednesday, April 9 (civil date), *Mars* was occulted by the bright limb of the moon, shortly after sunrise. The

occultation was observed by Messrs. HOLDEN and KEELER with the thirty-six-inch equatorial and by Professor SCHAEBERLE with the twelve-inch. From 14^h onwards the images had been very unsteady (weight 1) owing to a high wind; but just at the moment of the disappearance of the planet the seeing was average (weight 3). With the large telescope the observations were made by E. S. H., and noted on Chron. 1667 by J. E. K. The observed times reduced to Pacific standard time (Greenwich m. t. *minus* 8^h) were:

	h.	m.	s.	
1890, April 8	17	23	... ;	sun rises.
	17	48	07.4 ;	Contact I.
	17	48	39.7 ;	Contact II.

Professor SCHAEBERLE'S observations were:

	h.	m.	s.	
	17	48	5.9 ;	Contact I.
	17	48	39.5 ;	Contact II.

With the large telescope it was noted that the point of first contact on *Mars* was near to the preceding end of *Mare Sirenum*. *Nix Olympica* was visible. The unusual illumination of the sky, caused by the daylight and by the proximity of the moon, gave to the red parts of *Mars* a decidedly smoky appearance, quite different from the more vivid color under ordinary conditions. There was no shade on *Mars* parallel to the limb of the moon at any time, such as has been observed (here and elsewhere) at occultations of *Jupiter*. The limb of *Mars* suffered no distortion. Professor SCHAEBERLE'S notes follow:

"*Mars* appeared dark red, tinged with brown. The moon's surface was very much brighter than that of *Mars* and decidedly yellow. Not the slightest distortion of the planet's outline could be detected."

E. S. H., J. M. S., J. E. K.

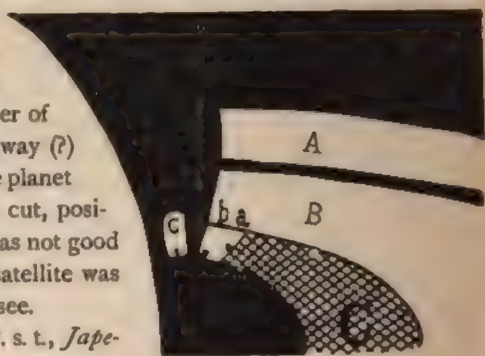
OCCULTATION (RE-APPEARANCE) OF *JAPETUS*, 1890, APRIL 9.

Dr. MARTH, in his indispensable "Ephemerides of the Satellites of *Saturn*," pointed out that on April 9, *Japetus*, the VIII Satellite of *Saturn*, would reappear from its occultation by the ball of the planet within the space between the gauze-ring and the planet, and after moving across this space would again be occulted by the ring, and would again reappear beyond the bright ring. Only the first part of this interesting phenomenon was observable at Mount Hamilton. Preparations to observe it were made by Mr. KEELER and

myself with the great telescope, and by Mr. BARNARD with the twelve-inch.

The seeing was generally good (weight 4 on a scale of 5). A magnifying power of about 700 was used by E. S. H. and of about 900 by J. E. K. The times given here are Pacific standard time (8^h slower than Greenwich mean solar time). The observations follow:

The *white spot* reported on *Saturn's* rings was specially looked for. Whenever the vision was especially poor for a brief moment, a slight confusion or lumpiness could be seen on rings A and B near the shadow of the ball on the ring. This disappeared the moment the vision improved. There seems to be little doubt that this phenomenon is due to bad atmospheric conditions, and to nothing else.



$10^h\ 52^m.0$, P. s. t., *Japetus* was first seen like a little knot on or near the square corner of ring B, or rather half-way (?) between the ball of the planet and ring B. (See the cut, position *c*.) The vision was not good at this time, and the satellite was extremely difficult to see.

At $11^h\ 02^m\ 48^s$, P. s. t., *Japetus* was noted as in the prolongation of the following edge of the shadow of the ball on the rings. (See the cut, position *b*.) The vision gradually improved. At $11^h\ 07^m\ 03^s$, P. s. t., it was noted that *Japetus* was in the position *b*, and this observation is satisfactory. At this time *Japetus* was about half as bright as *Enceladus*, which was near the preceding end of the ring.

At $11^h\ 11^m\ 03^s$, P. s. t., *Japetus* was slightly within the gauze-ring (C), about as far from the inner edge of ring B as the width of ring A where the shadow of the ball crosses A. At $11^h\ 24^m\ 13^s$, P. s. t., the satellite was barely visible. The preceding times were noted by E. S. H., and no other records were made, because the satellite was so faint that it appeared to the observer that no further observations of value could be made. It seems to be certain that even under the most favorable circumstances no object as faint as *Japetus* could possibly be observed through the CASSINI division between rings A and B.

At 11^h 39^m, P. s. t., J. E. K. noted that the satellite was no longer visible, and it was recorded that just before this it was distant from the inner edge of ring B by one-third of the width of the gauze-ring. (See the cut near *a*.) With a power of about 1400, J. E. K. could at times see the new division in ring A.

The satellite was carefully searched for by Mr. BARNARD with the twelve-inch, and no trace of it was seen or suspected. This result shows how delicate was the observation, and makes it probable that this phenomenon has not been observed elsewhere than at the Lick Observatory. E. S. H., J. E. K., E. E. B.

CONTRIBUTIONS OF ALBRECHT DÜRER TO ASTRONOMY.

[EXTRACT FROM A LETTER OF DR. C. H. F. PETERS.]

Apropos of a note with the above title in *Publ.* A. S. P. (vol. II, p. 20), I have received a letter from Dr. C. H. F. PETERS, Director of the Litchfield Observatory, of Clinton, New York, a portion of which I take the liberty of reprinting here. Dr. PETERS says:

"In the last number of the *Publications* is a little note of yours on the two star-maps published by HEINFOGEL, with the figures of the constellations drawn by DÜRER, which specially interested me, as a copy of these maps came into my possession a few years ago.

"By an accident, some copies of these maps were discovered in Vienna, and Professor WEISS* gave to me the copy which he had exhibited at the Kiel meeting of the *Astronomische Gesellschaft.* (See *V. J. S.*, vol. 22, p. 269.) I take great pleasure in presenting these maps to you, as I know you appreciate such historical documents.†

* * * * * * *

"Compare on these maps *Cetus* or *Piscis australis*, *Gemini*, *Boötes*, *Hercules*, which are quite original with DÜRER, with modern drawings. *Centaurus cum Lupo* resembles the drawing in SUFI, and that upon the Arabic globes somewhat. *Andromeda* has, with DÜRER, a rather awkward position. In the *Progymnasmata* of TYCHO BRAHE we find a drawing of *Cassiopea* that resembles DÜRER'S. The general and principal difference between DÜRER'S and the modern figures consist in this; that the former represents the figures as seen on the outer surface of the globe—that is, with their backs towards us. Queer contortions of the head thus originated, as, for

* Director of the Imperial Observatory at Vienna.

† These have been deposited in the library of the Lick Observatory, and will be exhibited to the meeting of the Astronomical Society, May 31.

example, in *Orion*, *Perseus* and *Auriga (Erichthonius)*, the latter almost incredible and not worthy of a DURER. Remark, also, the head-gear of the four astronomers in the corners! Those of MANILIUS and of AL SUFI may be all right; but that PTOLEMY should have worn a beaver-hat, or ARATUS what looks almost like a derby, one cannot well imagine! In the left-hand lower corner of the map for the southern hemisphere you will find the names of the authors—STABIUS, HEINFOGEL and DÜRER—and what each of them has contributed to the work."

I am sure that my friend Dr. PETERS will allow me to print this private note on a very interesting portion of the history of astronomy about which his ripe scholarship allows him to speak with authority.

W. M. CONWAY, Esq., of London, author of a work on DURER, kindly writes me to say that THAUSING'S Life of DURER (II, 122, 123, 180) refers to the maps in question. E. S. H.

REPORTS OF THE SOLAR ECLIPSES OF JANUARY AND OF DECEMBER, 1889.

The edition of the report of the eclipse of January, 1889 has been distributed, and there are no more copies on hand. The report on the December eclipse is in course of preparation. It will probably contain:

I. Reports on the Total Solar Eclipse of December, 1889, by Messrs. HOLDEN, BURNHAM, SCHAEBERLE, BARNARD.

II. Reports on the Total Eclipse of the Moon of July, 1888, by all the astronomers.

III. Catalogue of the Library of the Lick Observatory, by EDWARD S. HOLDEN. It will be illustrated with silver prints from the eclipse negatives and from drawings, etc. E. S. H.

"THE CALIFORNIA EARTHQUAKES (1850–88) AND THEIR RELATION TO ECLIPSES OF THE SUN AND MOON."

[BY DR. F. K. GINZEL].

Under this title Dr. GINZEL (Astronomer in the Royal Observatory of Berlin) has printed two articles in *Himmel und Erde* for March and April, 1890, to which attention is called. The immediate object of Dr. GINZEL'S essay is to demolish the theory by which Dr. FALB of Vienna claims to *predict* earthquakes; and this object is accomplished in a neat, workmanlike and unanswerable manner. His

discussion of the data has a wider interest than this however, and his remarks upon the philosophy of scientific method in general, are of permanent value. This is not the place to do more than to direct attention to this essay, which will have both a local and a general interest to our members. E. S. H.

Variations in the Latitudes of Berlin, Potsdam, Prague and Strassburg.

It is known that the four observatories named are making simultaneous determinations of their latitudes (by Talcott's method) for the detection of short-period variations in this element. During the first half of 1889 no variations were found. The observations of the last half of the year seem to show that there has been a diminution of the latitude at all these observatories, amounting to about half a second of arc. The work is to be continued.

The observatories of Pulkowa, Copenhagen, Upsala and Lund are engaged in observations to determine the long-period changes of latitude, if such exist.

The Latitude of Koenigsberg.

Dr. Rahts has compared his recent observations of *Polaris* with those of Bessel, with the object of detecting any change in the latitude of Koenigsberg in the past forty years. Professor Bruns of Leipzig, has reviewed Dr. Rahts' memoir in the *V. J. S. der Ast. Gesell.*, vol. 25, p. 15; and the following is a free translation of his remarks on the nature of this problem:

"It is theoretically certain that the latitudes of stations on the earth are subject to variation, just as all other data which depend on the arrangements of the masses of matter in the earth's interior.

"A whole series of processes can be named, any one of which necessitates a corresponding change in the latitude. Furthermore, it is certain, empirically, that these changes, so far as they are to be detected at all, at present attain only such magnitudes as are just barely measurable with the extreme delicacy of modern observations. If now we wish to investigate variations of the latitude, and to be independent of assumed values for the declinations of stars, we must have recourse to measures of the meridian-zenith-distances of circumpolar stars, since, for known reasons, observations of the sun are of less precision.

"The value of the latitude depends, therefore, directly on the amount of the refraction at the zenith-distance of the pole. If, then,

we reduce observations made at two different times with the same refraction-tables, any difference between the two observations depends not only upon the variation of the latitude, but also upon the differences between the tabular and the true refractions at the two epochs. It is, to say the least, illogical to simply assume in an investigation of this nature a datum which depends on meteorological conditions to be constant, without further research. In other words, it is essential in each determination of an absolute latitude, to determine also and at the same time the correction of the refraction-table itself. If, for example, we examine closely the well-known table of variations of the latitude of Pulkowa, which NYRÉN has printed in his memoir on this subject, we shall easily see that the above-mentioned requirement is, in general, *not* fulfilled. It is sufficiently strange, and yet the fact can easily be established, that a statement to the effect that all the variations in the different determinations of the latitude of Pulkowa at different times are solely due to errors in the assumed refractions, cannot be controverted without a new series of observations, or a more complete discussion of the materials now in hand.

* * * * * * *

"The latitude of Koenigsberg, from Dr. RAHTS' observations, is 54° 42′ 50″.43 (observations of 1886–1887); BESSEL'S value is 54° 42′ 50″.56 (observations of 1842–1844). No attention has been paid in these observations to the important point above mentioned. This objection does not apply to the present work alone: for a glance into astronomical literature will show plainly that many astronomers regard a refraction-table as very much the same thing as—let us say—a table of logarithms, and use it in the same manner."

LATITUDE OF WASHINGTON.

I have, among my papers, collections of all the observations available for such a discussion of the latitude of the Mural Circle of the United States Naval Observatory at Washington (1845–1878), and they are at the disposition of any one who has the necessary leisure to reduce them properly. Such a discussion would require a determination of the refraction and a thorough investigation of the division errors of the Mural Circle before it is dismounted from its place in the present observatory building. E. S. H.

Occultations of Stars at the Dark Limb of the Moon, Observed with the Twelve-Inch Equatorial.

By A. O. Leuschner.

1890.	L. O. M. T.	Star.	1855.0. R. A.	1855.0. Dec.	Remarks.
	h. m. s.		h. m. s.	° ′	
Mar. 26	7 32 30.4	DM. (+22°) 946	5 25 15	+22 19	Good.
" 26	49 57.8	DM. (+22°) 949	5 26 11	+22 28	Good.
" 26	58 53.2	DM. (+22°) 950	5 26 17	+22 25	Good.
" 26	8 0 14.4	DM. (+22°) 948	5 26 10	+22 22	Good.
" 26	1 1.7	DM. (+22°) 951	5 26 26	+22 38	No remarks.
" 26	26 38.8	DM. (+22°) 952	5 26 40	+22 20	Good.
" 27	7 17 46.1	DM. (+23°) 1356	6 18 10	+23 49	Good.
" 27	34 58.3	DM. (+23°) 1357	6 18 35	+23 47	Gradually.
" 27	58 50.2	DM. (+23°) 1362	6 19 9	+23 46	Good.
" 27	8 28 48.8	DM. (+23°) 1360	6 19 3	+23 32	Minute doubtful.
" 27	35 39.6	DM. (+23°) 1368	6 19 58	+23 40	Good.
" 27	42 23.8	DM. (+23°) 1371	6 20 5	+23 55	Good.
Apr. 22	7 41 47.2	DM. (+21°) 797	5 5 51	+21 44	No remarks.
" 22	45 8.1	DM. (+22°) 860	5 6 1	+22 4	Good.
" 22	52 7.5	DM. (+22°) 858	5 5 50	+22 10	*Good.
" 22	8 10 47.5	108 Tauri } ……	5 6 45	+22 7	Immersion, good.
" 22	52 51.7	108 Tauri }			Emersion, $\pm 0^s.5$.
" 22	9 46 10.8	*n* Tauri ………	5 10 34	+21 57	Good.
" 23	2 28 38.9	DM. (+23°) 1203	5 58 43	+23 45	Good.
" 23	38 35.5	DM. (+23°) 1206	5 59 6	+23 41	Good.
" 23	47 52.5	DM. (+23°) 1208	5 59 14	+23 46	Good.
" 23	56 2.1	DM. (+23°) 1210	5 59 25	+23 28	Good.
" 23	59 51.4	DM. (+23°) 1217	5 59 42	+23 42	Good.
" 23	8 11 58.8	DM. (+23°) 1212	5 59 29	+23 32	Good.
" 23	13 8.5	DM. (+23°) 1216	5 59 37	+23 23	Good.
" 25	7 32 2.2	DM. (+23°) 1833	7 44 15	+23 22	Seeing poor.
" 25	35 30.6	DM. (+23°) 1836	7 44 46	+23 28	

Lick Observatory, April 29, 1890.

* Entered the limb of the moon, and seen inside of the border for about 3^s; then suddenly disappeared.

Note on Photographing the Dark Part of the Moon.

It is found by experiments, made on the evening of April 21st, that the dark part of the moon, when the moon's age is 2.9 days, can be photographed with the twelve-inch Equatorial with a Seed 26 plate in twenty seconds—the complete outline of the dark part just showing with this exposure. With forty seconds and seventy seconds the dark part was conspicuous and details on it were clearly shown.

E. E. B.

Copies of Photographs taken at the Lick Observatory—How to obtain them.

The Director of the Lick Observatory has been authorized to supply copies of some of the negatives taken at Mount Hamilton to certain photographers, in order to make such copies available generally. Copies of some of our negatives have been furnished to quite a number of firms accordingly. Some of these firms (I. W. Taber, 8 Montgomery Street, San Francisco; Hill & Watkins, Santa Clara Street, San José, and Gayton A. Douglas & Co., 185 Wabash Avenue, Chicago,) are prepared to furnish prints, enlargements and lantern slides from such negatives as they now have. Other negatives will be furnished to them from time to time. E. S. H.

Companion of *Sirius*.

P = 359°.6	D = 4″.17	1890.252
361 .6	4 .20	.269
356 .8	4 .19	.304
359 .7	4 .19	1890.27

These measures were made with the 36-inch equatorial.

S. W. B.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD AT THE LICK OBSERVATORY, MAY 31, 1890.

A quorum was present. The minutes of the last meeting were read and approved.

The By-Laws as printed in *Publ.* A. S. P., Vol. II, pages 34, 35, 36, were adopted by the consenting votes of nine members, to wit: Messrs. ALVORD, BURCKHALTER, GRANT, HILL, HOLDEN, MOLERA, PIERSON, SCHAEBERLE, ZIEL.

The following resolutions were adopted:

Resolved, That the consenting votes of nine members of the Board of Directors shall be required for the election of an Honorary or of a Corresponding Member.

Resolved, That the bond to be given by the Treasurer A. S. P. be fixed at $5,000.

Resolved, That the Society will assume the loss of the dues for 1890 of Rev. C. M. CHARROPPIN (lost in the mails, February 11, 1890).

Resolved, That the President and one of the Secretaries be authorized to sign a paper, accepting the arrangement kindly offered by the Trustees of the Mercantile Library Association, relating to the care of the books belonging to the Library of the A. S. P. and of the books of the MONTGOMERY Library.

The following thirty-three members* were then elected by the Directors:

SETH BABSON,	408 California Street, S. F., Cal.
N. Y. BAILEY,	Early Grove, Mississippi.
A. CAMERON,	Yarmouth, Nova Scotia.
FREDERICK H. CHAPIN,	Hartford, Connecticut.
Rev. C. M. CHARROPPIN, S. J.,	University of St. Louis, Mo.
ISAAC Y. CHUBBUCK,	Roxbury, Mass.
Mrs. M. THORNBURGH CROPPER,	1023 Ellis Street, S. F., Cal.
EARNEST I. DYER,	966 18th Street, Oakland, Cal.
OLIVER EVERETT,	408 California Street, S. F., Cal.
Mrs. J. A. FILLMORE,	Occidental Hotel, S. F., Cal.
Dr. DAVID GILL, F. R. S.,	*Royal Astronomer, Cape of Good Hope, Africa.*
N. H. HEMING,	604 5th Street, S. E., Minneapolis, Minn.
President A. C. HIRST,	University of the Pacific, College Park, Cal.
JOHN R. HOOPER,	Howard Nat. Bank, Baltimore, Md.
C. W. IRISH,	Reno, Nevada.
TORVALD KÖHL,	Odder, Denmark.
HENRY B. LOOMIS,	Seattle, Washington.
Prof. A. A. MICHAELSON,	Clark University, Worcester, Mass.
Hon. ALBERT MILLER,*	532 California Street, S. F., Cal.
Miss GRACE MORRILL,	Occidental Hotel, S. F., Cal.
Mrs. PAUL MORRILL,	Occidental Hotel, S. F., Cal.
C. MOORMAN,	What Cheer, Keokuk County, Iowa.
C. J. NICKERSON,	Oroville, Cal.
CHARLES LANE POOR,	Johns Hopkins University, Baltimore, Md.

* An asterisk (*) is affixed to the names of Life Members duly elected. Addresses in italics are not within the Postal Union.

Prof. H. S. PRITCHETT, ...	Observatory of Washington University, St. Louis, Mo.
Dr. H. C. SAWYER, ...	1320 Market Street, S. F., Cal.
RICARDO SCHOTT Y LARIOS, ...	Malaga, Spain.
Rev. GEORGE M. SEARLE, ...	Catholic University of America, Brookland, D. C.
MELVILLE SMITH, ...	24 Winthrop Street, Augusta, Me.
C. F. A. TALBOT, ...	204 California Street, S. F., Cal.
RICHARD M. TOBIN, ...	Hibernia Bank, S. F., Cal.
W. R. WARNER, ...	Care of Warner & Swasey, East Prospect Street, Cleveland, Ohio.
WILLIAM C. WINLOCK, ...	Smithsonian Institution, Washington, D. C.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT THE LICK OBSERVATORY, MAY 31, 1890.

The minutes of the last meeting were read and approved.

The Society was notified that the By-Laws as printed in Vol. II, pages 34, 35, 36, had been adopted.

The list of new members elected was read by the Secretary.

The Committee appointed March 29, to report upon a plan for establishing an observatory for the members of the Society, asked for more time and was continued.

The following papers were presented:

a. "The Eclipse of December 21, 1889," by EDWARD S. HOLDEN.

b. "The Astronomical Society of Camden, New Jersey," by A. B. DEPUY, Secretary.

c. "Elements of Comet BROOKS (March 19)," by A. O. LEUSCHNER.

d. "On the Criterion of Continuity of Functions of a Real Variable, and on the Theorem of Mean Value," by Professor I. STRINGHAM.

e. "Does the Color of a Star indicate its Age?" by WILLIAM M. PIERSON.

f. "Remarks on the Mechanical Theory of the Corona, previously proposed," by Professor J. M. SCHAEBERLE.

g. "Note on the Definition, the Resolving Power and the Accuracy of Microscopes and Telescopes," by Professor A. A. MICHAELSON.

Owing to lack of time, only *e* and *f* were read. All the papers except *f* are printed in the present number of the publications.

Adjourned.

CORRECTIONS TO DR. KREUTZ'S ARTICLE ON DIE ASTRONOMISCHE GESELLSCHAFT.

Dr. KREUTZ calls attention to the necessity for the following corrections to the translation of his original article as printed in *Publications* A. S. P., volume II, page 41. The expression "German Astronomical Society" was not employed by the author, and does not truly represent the *international* character of the Society. On page 45 (line 19) *for* "naturally" *read* "in reality."

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year.

It is intended that each member of the Society shall receive a copy of each one of the Publications for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied.

Members are requested to preserve the copies of the Publications of the Society as sent to them. Once each year a title page and index of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume.

Complete volumes for past years (preceding the calendar year in which any member was elected) will also be supplied to members, so far as the stock in hand is sufficient, on the payment of one dollar to either of the Secretaries.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," at the rooms of the Society, 408 California Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.


URANIA
Physik
Wissenschaftl. Theater
Microscopie

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

Vol. II. San Francisco, California, July 12, 1890. No. 9.

THE URANIA GESELLSCHAFT.*

By Dr. M. Wilhelm Meyer, Director.

A few months ago *Himmel und Erde*, the journal published by the Urania Society, printed a most interesting description of the construction and scientific work of a great American observatory—of that observatory which is regarded by all astronomers of the world with a certain kind of envy, but at the same time with the pride which naturally results from the close association of the interests of all astronomers, of whatever nation; for we all know well that the possession of this great instrument of investigation, which had its origin in the munificence of a single individual, and has been so happily wrought out to completion, must advance the cause of astronomical science in every part of the world.

Professor Edward S. Holden, the Director of the observatory referred to, has now, on his side, requested me to prepare an account of the founding of the Urania Institution, with which I have been closely connected from the very beginning, and which has been in close relations with the Lick Observatory from that time, since the two establishments have in many respects a similar aim. A further parallel can be drawn between the two institutions, namely: the Urania Institution, like the Lick Observatory, is devoted to the advance of scientific knowledge, although with less powerful appliances and instruments; it owes its origin to private capital, and depends for its support upon the interest of the great public in scientific investigations. It is with so much the greater pleasure therefore that I have prepared the following description of our own institution.

In view of the continually increasing interest which the public takes in the natural sciences and in their manifold applications to the affairs of every-day life, the founders of the Urania Institution long

* English translation by J. E. Keeler.

ago resolved to establish some popular scientific centre or building in which the desires of the people for increased knowledge in these directions could be satisfied. The original plan of Professor FOERSTER for a popular observatory, arising from the pressure of visitors at the Berlin Observatory (of which he is Director), and the consequent disturbance of the scientific work of the institution, was, by the advice of Dr. M. W. MEYER, the present Director of the new institute, so modified as to include physical, microscopical and other branches of natural science. An auditorium or scientific theatre, in which curious or remarkable natural phenomena could be presented to the public by the aid of scenic art, was also included in the plan.

The Prussian Minister of Public Instruction, Herr VON GOSSLER, at once took the warmest interest in the project, and placed the necessary site for the building at our disposal, in the park for the national exposition at Berlin.

On the 3d of March, 1888, the patrons of the new undertaking, at that time already numbering 122, met and formed a joint-stock company—but a stock company of such a remarkable character as has perhaps never before existed. The shares (each of 500 marks or about $125) are not transferable, and they cannot be bought or sold. The object of the company is defined to be simply the diffusion of pleasure in the pursuit of the knowledge of Nature. Yearly dividends, not to exceed five per cent., may be paid, if justified by the financial success of the undertaking. Every member has the right of admission to all lectures or other entertainments, and receives free of charge the illustrated journal, *Himmel und Erde*, published monthly by the society. The available capital at the time of incorporation was about $51,000, and has since been increased to $100,000, while the number of members is now 375.

The Board of Directors is at present composed of the following members:

President, Professor H. LANDOLT; *Vice President*, Dr. H. PAETEL; Herr T. HEESE; H. HERZOG; Dr. M. MARCUSE; Herr T. SCHIFF; Herr W. VON SIEMENS; Herr W. ZWICKER.

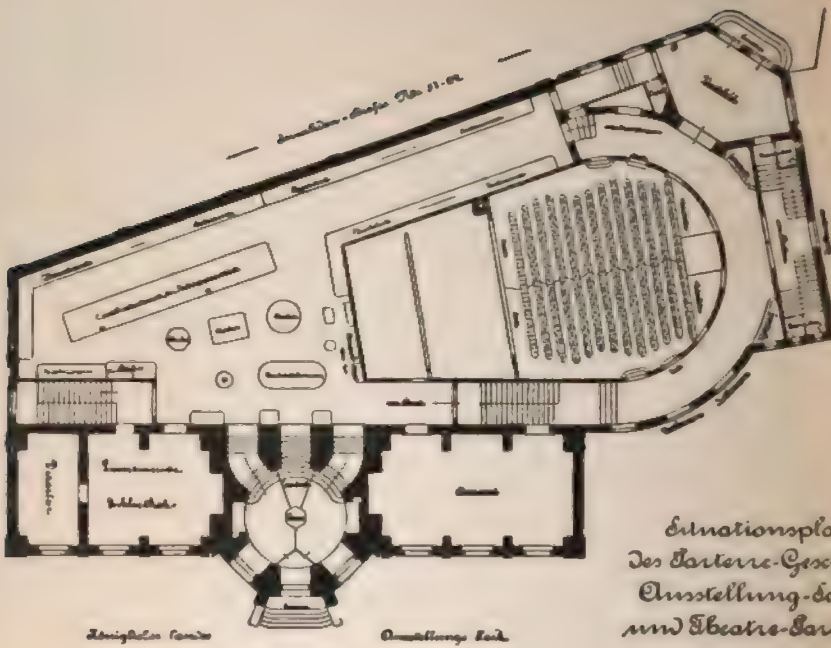
The Council of the Society is composed of the following persons:

The President: Herr Geheimer Regierungsrath Professor Dr. W. FOERSTER (Director of the Berlin Observatory).

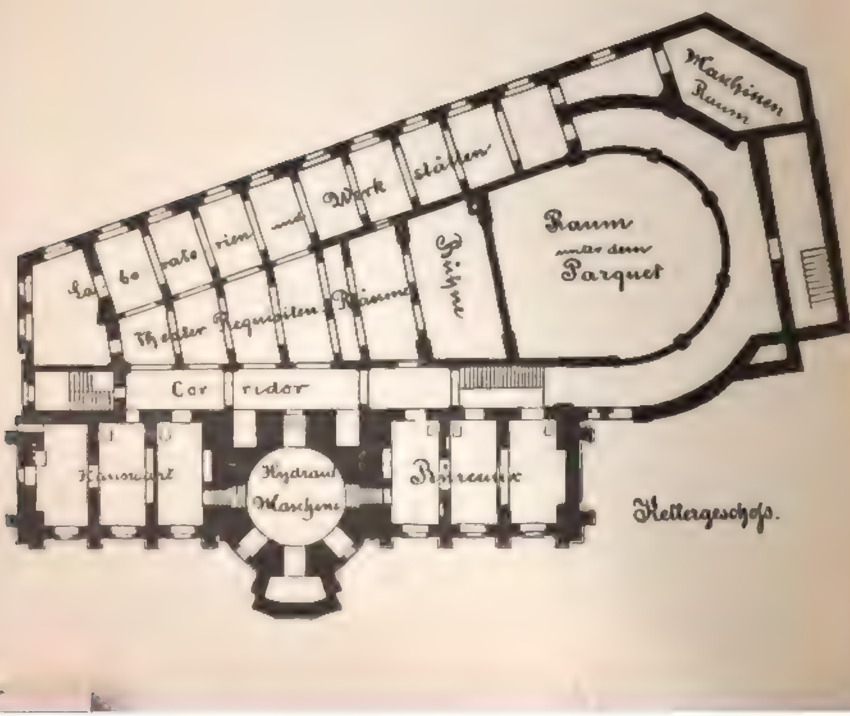
The Director of the Society: Dr. MAX WILHELM MEYER.

Member on behalf of the Königliche Staats-Regierung: der vortragende Rath im K. Unterrichts-Ministerium Herr O. NEUMANN.

Herr Rentier A. TOST.



Situationsplan des Parterre-Geschosses Ausstellung-Saales und Theatre-Parquets.



Kellergeschoß.

The direction of the work of construction was undertaken by Geheimer Oberregierungs-Rath Herr SPIEKER, by the authority of the Minister of Public Instruction. The designs for the building were perfected by Herr DITMAR, Landesbauinspektor, and the building erected in accordance with these plans by Herr ANDREE, Regierungsbaumeister. The accompanying photo-lithograph shows the principal façade of the completed building, and the various figures give the plans of the different stories. The institution was first opened to the public on July 2, 1889, and at the end of the year had been visited by not less than 60,000 persons.

The work of the institution is divided into five principal departments, the astronomical, physical, mechanical, microscopical, and the department of scientific lectures in connection with the auditorium, to which may be added the editorial management of the monthly journal. Each of these departments, with the exception of the mechanical, is under the supervision of a special official. The superintendent of the Astronomical Department is at present Dr. F. KÖRBER; the former superintendent, Dr. M. ZWINK, having accepted the position of Assistant in the Strassburg Observatory. With him are associated Herren ARCHENHOLD and SCHWAHN, and a number of younger astronomers, who assist with the telescopes on public evenings. The Physical Department is under the general direction of Professor E. GOLDSTEIN; Herr P. SPIES is superintendent, assisted by several younger physicists, who aid in instructing the public in the use of the instruments. The Microscopical Department is under the general direction of Professor W. PREYER, but the office of superintendent is as yet vacant. The auditorium is in charge of Herr W. KRANZ, who has the supervision of the scenic arrangements, machinery and apparatus connected with the public exhibitions. The more strictly business affairs of the Association are managed by Herr BRUCK. There are about thirty minor officials and employés in the different departments, so that some forty persons are engaged in carrying on the work of the institution, exclusive of the editorial staff of the journal.

I shall now endeavor to give a somewhat more detailed account of the equipment and work of the different departments. The principal instrument of the Astronomical Department, and the one which may be regarded as the main attraction of the establishment, is a twelve-inch refractor with objective by SCHOTT & Co. of Jena, which in Germany is only exceeded in size by the telescope at Strassburg. The figure of the glass, as well as the workmanship of the

mechanical parts of the mounting, appear from the tests we have been able to apply up to the present time to be of great excellence.

The instrument is provided with a filar micrometer, a polarizing helioscope, and a complete set of eye-pieces ranging in power from 70 to 1,300 diameters. Photographic and spectroscopic apparatus has not yet been supplied. Among the novel or interesting details of the attachments may be mentioned the electrical illumination of the circles and micrometer, and the electrical driving-clock, which is similar to the one used on the ten-inch refractor at Geneva. In this arrangement the current from a storage battery drives an electric motor attached to the clock-work, its power being regulated by a conical pendulum.

Since it is the object of our institution not only to exhibit natural phenomena and the workings of natural forces, but to illustrate the applications of mechanical and technical skill in their study, the latest mechanical devices have been employed in the equipment. The dome of the twelve-inch refractor, for example, is provided with a hydraulic elevating floor similar to the one in use at the Lick Observatory, capable of lifting twenty persons into the most convenient position for observation. The dome, twenty-six feet in diameter, is also rotated by hydraulic power, and the shutter closed by the same means. An arrangement will be added by which the rotation of the dome can be electrically controlled from the eye-end of the telescope.

The Urania Observatory has also five other telescopes. A six-inch refractor, with optical parts by REINFELDER and HERTEL and mounting by HEYDE, stands in the smaller dome, on the east. It is provided with clock-work and micrometer. In the west dome is a simple four-inch equatorial, also with clock-work. On the west platform, in the open air, but protected by canvas covers, are a six-inch reflector, with alt-azimuth mounting, and a two-and-a-half-inch transit instrument for time observations. On the east platform is an equatorially mounted comet-seeker of five inches aperture, the optical arrangements of which offer some peculiarities of construction. The objective is of Jena glass, with curves worked according to GAUSS' formula, the outer surface being concave. This combination gives a remarkably large field and great brilliancy.

The four last described instruments and the mechanical parts of the twelve-inch refractor are by CARL BAMBERG, of Friedenau, near Berlin.

The standard clock of the observatory, by TIEDE, stands in the vestibule of the large dome, and electrically controls two less perfect

clocks, one in each of the small domes. One of these in its turn controls a dial in the large dome. Electric connections extend from all parts of the observatory to a chronograph, on which the exact time of an observation can be recorded by means of the standard clock.

All these arrangements are of the latest and most improved designs, and have, of course, not been provided merely for the satisfaction of public curiosity, but for the prosecution of scientific research.

It is a well-known fact, which we have already been able to fully verify, that the great majority of visitors are not greatly edified by a view through a telescope. It is true that an observatory possesses a great attraction for the public; each person expects to see undreamed-of wonders in the worlds above us when he looks into an instrument. The disappointment is therefore very great when, for example, the brilliant light of the full moon has attracted crowds of visitors to the observatory, and it is necessary to explain to them that even the best telescopes show but little on the full moon, and that the most favorable time for observation is when the moon is near quadrature; or when they are shown a fixed star, and learn that the minuteness of the point of light seen in the telescope is owing to the immense distance of the suns scattered through space. Instructive articles in the papers setting forth these facts are of but little service. It is necessary to gradually modify the erroneous impressions of the public by a more thorough and striking method of instruction; and to this end we must pursue a proper course with our own astronomical workers, and give them opportunities to carry on actual scientific investigations. In this way only can they fully succeed in imparting a knowledge of the pleasure which arises from a comprehensive glance into the secrets of nature.

When, on account of the throngs that come to the observatory on clear evenings, the time allowed to each person is less than is required for a complete satisfaction of his wishes, and one is compelled to leave the telescope somewhat dissatisfied, we ask such a visitor to pass from the observatory itself into the auditorium, where instruction is given on the subject of the heavenly bodies, illustrated by means of views projected on a screen, by the aid of a light of 6,000 candle-power. From the mutual support of the two departments our visitors derive a pleasure which would otherwise be lost. In the first half year as many as 503 such lectures, each of half an hour's duration, were given in the auditorium, and a continually increasing collection of lantern slides, now about 700 in number, has been used in illustrat-

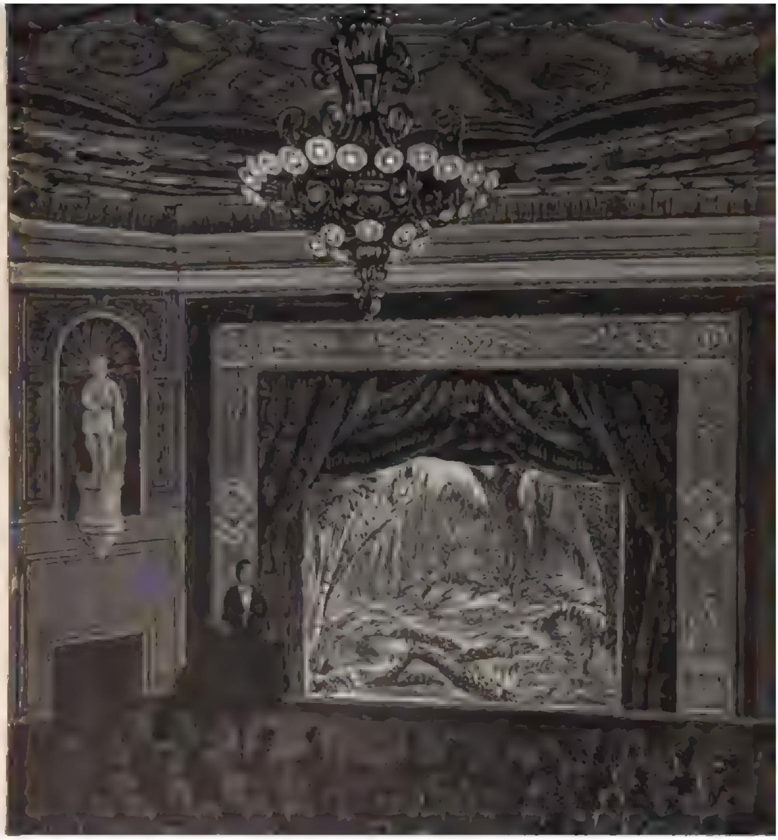
ing them. These lectures were not all, however, devoted to astronomy, but covered the various subjects within the scope of the institution.

The Physical Department is even more attractive to the visitors of Urania than the Astronomical, and this is largely due to the novel manner in which Professor GOLDSTEIN has arranged the apparatus. In all other museums and collections, handling the instruments is strictly forbidden; but here they are so contrived that the visitors, by touching an electric button, can set the machinery in motion. If, for example, the visitor presses a knob on the first case of the electrical collection, he sends a powerful current from the storage batteries through a spiral of platinum wire, by which the wire is heated to incandescence, and he is taught one of the simplest effects of the passage of an electric current through a resisting medium. The next case contains a somewhat similar piece of apparatus, but quite a number of different metals are acted on by the current. Another case illustrates the decomposition of water by electricity; another, the reverse of this process, the production of a current by chemical combination. In the same way are illustrated all the most important and interesting phenomena of electrical action, such as the magnetic effect of a coil transmitting a current, the mutual attraction or repulsion of currents and their inductive effects, as well as the operation of instruments based upon these principles.

Opposite to the electrical is the optical collection, where we find mirrors and lenses illustrating the formation of images; spectroscopes, with which the spectra of various substances can be examined at pleasure by pressing a knob; polariscopes, GEISSLER and CROOKES tubes, illuminated in the same manner, as well as a great number of other instruments.

The electric current which serves for these instruments and for the other purposes of the institution, is furnished by ten large storage batteries, which are charged by a dynamo, driven by a twelve-horse-power gas-engine in the cellar. From the storage batteries wires lead to all parts of the building. All the electrical machinery and connections were supplied by the firm of SIEMENS & HALSKE, of Berlin.

It is impossible to even mention the great number of instruments in the Physical Department, some of which, as, for example, those in the acoustical collection, excite great interest in the public. But we must make special reference to the phonograph, which, on account of its pecular interest, is mounted in a room by itself. Unfortunately, this instrument, like a telescope, can be used by but one or at most a very few persons at a time, and it becomes necessary to admit vis-



itors in regular order, as at the telescopic exhibitions. Two complete phonographs, with many accessories (cylinders with musical pieces, etc.,) have been generously presented to the institution by Mr. EDISON, and the skill of our own physicists has largely increased the equipment. With these instruments special exhibitions are given, on certain evenings, at advanced rates.

After the Physical Department comes the Microscopical, introducing us to the wealth of animate and inanimate forms which surround us on every side, but which would be forever unknown to the unaided vision. We may regard the Physical Department as a connecting link between the Astronomical and the Microscopical, the whole bringing before our minds a true picture of nature, and teaching us what we are perhaps too apt to forget in contemplating the vast bodies dealt with by astronomy—that every infinitesimal particle of these is itself a world of wonders, whose place and purpose in forming the mighty whole of creation is hidden from all except Infinite wisdom.

Of the vast number of objects which offer the greatest instruction and entertainment under microscopical examination, only a few can be exhibited in the institution. Fifty compound microscopes, and many simple ones, are mounted in favorable situations in the building. In some of these are crystals showing the beautiful colors produced by polarized light; in others diatoms, low forms of animal life, parts of insects, and other preparations selected by Professor PREYER as best illustrating the variety of curious forms abounding in the land and sea. Among the interesting features of this department is a piece of apparatus which renders visible the development of the chick, the egg being warmed by electricity in a manner devised by Professor PREYER. Joining this department is a collection of scientific instruments by various makers in Germany, illustrating the most refined devices for exact measurements and physical investigations. These instruments are exhibited by permission of the institution, and are for sale.

The fifth department of our institution consists of the scientific theatre, or auditorium, and its adjuncts. The nature of the entertainments given here has been stated above. The stage, which has already been found somewhat too small for its purpose, is a copy on a small scale of the stages of our large theatres, with all the mechanical devices used in them, and was planned by Herr BRANDT, of the Royal Theatre of Berlin. The electric lighting is by SIEMENS & HALSKE, and the hydraulic machinery of the stage by C. HOPPE &

Co., who were also the builders of the dome for the twelve-inch equatorial.

It is evident that many additions to the ordinary outfit of a theatrical stage are required for the purposes of the Urania exhibitions. Since there are no actors, a floor is not ordinarily required, the lecturer standing at a small desk placed on one side, but it is placed in position for the lectures on experimental physics, the stage being then occupied by a long table. For exhibitions which are illustrated with lantern projections, the whole area occupied by the curtain is filled with a white screen, and the views are projected by a lantern having a 6,000 candle-power electric light at the other end of the room. The apparatus, by Plössl & Co., of Vienna, is arranged to project opaque as well as transparent objects, microscopic preparations, and polariscopic and spectroscopic phenomena. For the present the short afternoon lectures that were given during the first half year of our existence have been discontinued, and longer entertainments are given in the evening. Two illustrated lectures prepared by the present writer, entitled "From the Earth to the Moon," and "The History of the Primeval World," have been repeated by Herr Bergmann one hundred and twenty times. Other subjects have been "Light," "Heat," "Sound," "Electricity," "The Sun," "The Moon," "The Planets, Comets and Meteors," "Life in the Depths of the Ocean," "The Relations between Plants and Animals," and many others, drawn from the domains of physics, astronomy and biology.

Attention may be called here to the fact that our entertainments are not mere lectures, but are given with all due regard to spectacular effect, the assistance of the scenic artist and stage mechanician being called upon to supplement the work of the physicist or the astronomer. By this appeal to the senses of the spectator and his love of the beautiful and the striking, we believe it is possible to make a deeper impression than if the appeal were made to his intellect alone. In the "History of the Primeval World" the spectators see the gradual evolution of the earth from the chaos of the original nebula; they see the lightning and the eruptions, and hear the thunder of the tremendous struggle between fire and water as the earth gradually cools, and trace in the shifting scenery the changes which led up to its present peaceful condition.

Once or twice a week, more technical lectures, addressed to smaller circle of hearers, are given, in place of the entertainme just described.

Instruction of a still higher grade is also given by the institution,

in the form of lessons on the use of astronomical and physical instruments, and the proper manipulation of the microscope, and lectures on these and other subjects will be given during the next winter.

In the basement of the building are the laboratories, and the machinery used for the various purposes of the institution, as will be seen on consulting the plan. Among the more important mechanical devices we may call especial attention to the gas-engine, which drives a dynamo for charging the storage batteries, and a force-pump for replenishing the hydraulic reservoirs; and to the machinery connected with the hydraulic apparatus for raising the floor and turning the dome of the large telescope. From here also starts the maze of water and gas pipes, electric cables and telephone wires which is spread throughout the building above.

We have found, with satisfaction, that the advantages offered by the various departments of Urania outlined above have been recognized by all classes of society. Over 60,000 persons visited the institution during the first half year of its existence, as has been said. Among these were a great number of students, in whose favor a reduction of half the regular price was made, and many teachers of the city schools, who are admitted free. School children under the care of their teachers have also been admitted, since the middle of November, three times a week, during the forenoon, and special entertainments are given every Sunday morning to workingmen at an entrance price of only twenty pfenninge (five cents). Various societies and corporations have secured the privilege of exclusive attendance during the afternoon hours on Sundays, and the doors are then not opened to the general public until three o'clock. The permanency of our institution is assured beyond doubt by this great and increasing popularity, and the satisfaction in its management that we are assured is felt by all becomes in the highest degree our own.

Since the foregoing article was put in type, the Report of *Gesellschaft Urania* for the past year has been received. From this interesting paper the following notes are taken: Since the opening of the institution to the public, visitors have been admitted on 268 days, and no less than 95,000 persons have availed themselves of the privilege. Among these must be counted 5,600 students, 7,900 members of various societies, 5,600 members of workingmen's societies, and 11,100 pupils from the city schools. The greatest number of visitors on any one day was 1,310. Three hundred and thirteen lectures of about ninety minutes long, and five hundred and eighty-two lectures of thirty minutes in length, have been given.

The receipts for the 268 days in question have been over $26,000 (or about

$98 per day). The greatest receipt for a single day has been $221. The expenses for a whole year have been:

For salaries, etc.	(about)	$13,380
" supplies, etc.	"	6,549
" advertisements, etc.	"	2,372
In all	(about)	$22,301

The journal, *Himmel und Erde*, has at present 1,500 paying subscribers, and has cost some $3,800 more than the receipts from subscribers. It has rendered most valuable service to science, not only by its important articles, but also by its capital reproductions of astronomical and other drawings and photographs. In this direction it has already conquered an absolutely unique position.

The foregoing statistics speak eloquently of the immense usefulness of this popular astronomical institute in its very varied relations, and the splendid success of its first year's work is a promise for its continued prosperity in the future. The benefits which such an establishment confers are manifold and far-reaching —from instruction to thousands of pupils in the schools up to opportunities of research in many branches afforded to skilled scientists. It is to be hoped that the brilliant success of *Gesellschaft Urania* may lead to the establishment of similar institutions in the different countries of Europe and of America. Fixed observatories already established can do no more useful work than by co-operating with such popular institutions in the fullest manner. E. S. H.

ASTRONOMICAL PHOTOGRAPHY AT THE LICK OBSERVATORY.*

By Edward S. Holden.

The editors of the *International Annual* have kindly asked me for an account of our photographic work at the Lick Observatory, and although (for reasons not necessary to state here) our work of this kind has but just begun, I am very glad to comply with their request, and to give very briefly our experience up to this time.

The experiments so far made indicate that the photographic lens (thirty-three inches aperture, 570 inches focus) will be found as satisfactory as the visual objective, thirty-six inches aperture, 694 inches focus. Both of these were made by Alvan Clark & Sons. The mounting of the great telescope is by Warner & Swasey of Cleveland, and this also has proved to be very satisfactory. The dome of seventy-five feet diameter (made by the Union Iron Works of San Francisco), with its elevating floor (sixty-one feet in diameter),

* Reprinted (with additions) from the *International Annual of Anthony's Photographic Bulletin, 1890*.

has worked well, and the latter has proved itself to be almost essential in photographic operations with so great a telescope.

A number of subjects have hardly been touched at all, such as the photography of planets and direct enlargement; and the various difficulties in our other work are not yet all conquered, or even understood, but enough has been done to show that success can be attained. The observatory is very fortunate in counting among its astronomers Messrs. BURNHAM and BARNARD, whose photographic skill and experience is equal to their astronomical ability. The other astronomers engage in the work of exposing and measuring the negatives, but all the photographic work proper has been done by these gentlemen in addition to their other duties.

PHOTOGRAPHS OF STARS.

In astronomical photography of stars we may have different objects in view. We may wish for a picture of the stars merely; or to measure their distances apart; or, finally, to determine their photographic brightness. The stars may be photographed as *dots* (*i. e.*, with the telescope driven by clock-work to follow the stars in their courses from rising towards setting) or as trails (the stars moving across the stationary plate from east towards west). In the first case (dots), we secure the impressions of fainter and fainter stars, according as the exposure is longer and longer. In the second case, we shall have no trails from the fainter stars, on account of the short exposure. With the great telescope a star on the equator moves $\frac{35}{1000}$ of an inch on the plate in one second of time, and $2\frac{1}{10}$ inches in one minute of time. Hence, only the brighter stars (about 7th magnitude or so) register their trails at the equator. The stars near the pole move very much slower, and stars of the 13th or 14th magnitude will trail.

To obtain star pictures or maps, long exposures are necessary with any telescope. If the instrument is intended to register the greatest possible number of stars, it should have a focus relatively short. Refractors with a double objective, on the model of a portrait combination, have a great advantage in this respect. The Harvard College Observatory has been using portrait lenses of eight inches aperture and forty-four inches focus for this purpose, and is now making a similar lens of twenty-four inches aperture and eleven feet focus. Reflectors are very suitable also, and, in my opinion, the next great telescope for photography should be a reflector of large aperture and short focus. Mr. COMMON, of London, has just

mounted a five-foot reflector of this class, and its performance will be eagerly watched, in order to see what work is to be expected from instruments of this construction.

If stars are to be taken as dots, the clock must follow the motion of the stars very accurately, or else the telescope (or the photographic plate) must be moved by hand from time to time, to correct the irregularities of the clock-work motion and the small changes in the star's apparent position, due to refraction, etc.

In the Lick telescope, the photographic focus is forty-seven feet six inches. The slightest wandering of the axis of the telescope, or the slightest flexure of the tube, etc., will produce a comparatively great displacement of the image on the plate.

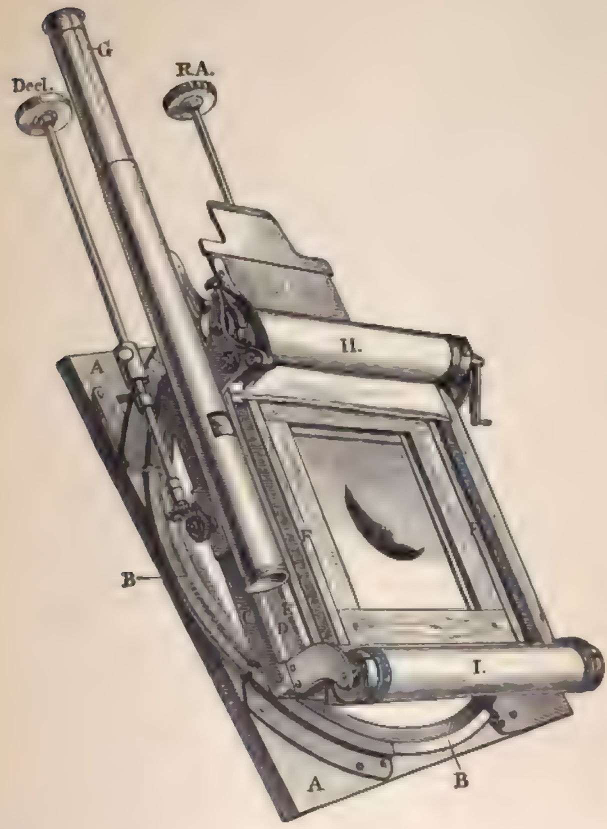
Our driving-clock is electrically controlled from a standard clock, so that it goes at precisely the right rate. But we still find it necessary to move the plate by hand (by means of two screws at right angles to each other), to correct the minor irregularities of the train beyond the clock, refraction, flexure, etc. A guiding eye-piece is attached to the plate itself, and a guiding star is kept exactly at the intersection of two wires in the eye-piece, by moving a slide which carries both plate and eye-piece. (See the accompanying plate.)

Such a long-focus telescope as ours cannot produce maps of the faintest stars as easily as such maps can be made by shorter-focused instruments. On the other hand, we have an immense advantage in the scale of the picture. $1''$ of arc $= 0.003$ inches; $0''.01 = 0.00003$ inches. It is easy to measure the distance apart of two dots or trails (under a suitable microscope) correctly to $0''.03$ or so. Hence, the relative positions of stars (or of craters on the moon, etc.) can be accurately and quickly fixed from our negatives.

To detect shrinkage of the film, we impress the image of a reticle ruled in squares on the negative before exposure, and, on development, we have these squares displayed. A comparison of the squares of the reticle with the squares of the negative will detect distortions of the film, etc. For accurate measures our negatives must be made on plate glass. The beautiful reticles which we have were ruled at the Potsdam Observatory by Professor H. C. VOGEL and Dr. SCHEINER.

Thus, wherever scale is of importance, as for measures of parallax, etc., the great telescope has a decided advantage over shorter-focused telescopes. A distance of $2000''$ to $3000''$ of arc can be measured with a probable error of not more than $0''.1$ or $0''.2$.

Trails of stars can be used to measure differences of declination



COMPOUND SLIDE-REST FOR CARRYING THE NEGATIVE PLATE OF THE THIRTY-SIX-INCH EQUATORIAL.

(By the courtesy of the Council of the Royal Astronomical Society.)

The mechanical parts made by WARNER & SWASEY; the optical by J. A. BRASHEAR.

The frame A A is fixed in the tube at right angles to the optical axis. The frame D and everything above is movable in declination by the handle Decl.; the frame E and the eye-piece G are movable in right-ascension by the handle R.A. The guiding eye-piece G receives a beam from the object-glass, and the image of a star is kept on its cross-wires by suitably moving the handles. The wires are lighted by a small incandescent lamp. The plate-holder shown in the cut is 8 × 10; the image of the moon is about five inches in diameter. I and II are curtains on spring rollers, for quick exposures. The two handles and the end of G project several inches outside of the telescope tube.

(perpendicular to the trails), and thus to determine parallax, etc. Trails are also suitable for measures of the photographic brightness of stars. For this purpose, it seems best to give all stars the same exposure, and this can be effected (as suggested by Mr. SCHAEBERLE of the Lick Observatory) by causing the plate to follow the stars in right ascension, but to trail in declination; that is, to make the stars impress themselves on a plate which follows their motion from east to west, but which is also driven by a second clock-work at a uniform rate from north to south. Every star sufficiently bright can thus be compared with *Polaris*, and the photographic brightness of each star, in terms of that of *Polaris* as unity, can be deduced. The same thing can be (less accurately, I think,) determined by measuring the diameter of the images of the various stars, and by comparing the diameters of the various stars with that of *Polaris* on the same plate.

The subject of photographic photometry is a very difficult one, both theoretically and practically, and involves a knowledge of the relation between the intensity of the stain on the plate and the exposure time. Captain ABNEY, whose authority is of the highest, has come to the conclusion that "the deposit of silver made by different intensities of light, varies in density* directly as the intensity of light acting—this, of course, within such limits that the reversal of the image is not commenced, and that the film is not in any part exhausted of the silver salt that can be reduced." Our own experiments on this subject (which are just begun) seem to indicate a somewhat less general conclusion.

As the question is fundamental, it may not be improper to give the conclusions we have so far attained, with the proper reserve, since further experiment may modify the results now apparently reached. For a light of a given intensity, I, for example, it seems to follow from our work, that for very short exposures the density of the deposit D increases very much faster than directly as the time, T. For longer exposures, the density D' becomes more nearly proportional to T'; for still longer exposures, the proportion again falls off, long before the halation stage is reached.

Thus, for light of intensity, I, we have from zero to T; D varies more rapidly than directly as the time; from T' to T'', D varies as the time; from T'' to T''', D varies less rapidly than directly as the time. For light of intensity, i, the density d goes through these three stages of different intervals $t' - o$; $t'' - t'$; $t''' - t''$.

A very important point seems to be that t' is not the same as T';

* I understand this to mean "varies in opacity," though I may misinterpret the expression.

t'' not the same as T'', etc., but that t varies with i. That is, if the deposit on a given plate is proportional to the time, between five seconds and ten seconds, for example, for a light, i, it will not be proportional to the time between these limits for a light of greater intensity, I. For I, it may be so proportional between other limits of exposure, as three seconds and seven seconds and so on.

If these results are true, they seriously modify photometric conclusions hitherto reached by means of photography.

I have been willing to speak at this time of experiments which are still in progress, and whose results are by no means final, on account of the great importance of this question, and in the hope of inciting others to experiments on the same subject.

Mr. SCHAEBERLE has found that if d be the diameter of a star-image (dot) taken with a six-inch DALLMEYER portrait lens in a time t on a Seed 26 plate, with a diaphragm Q inches in aperture in front of the objective, that we can express this diameter as follows:

$$d = A + B \log Q + C . Q . \log t.$$

A, B and C are constants which must be determined for each plate. It is probable, though not proved as yet, that this equation is only true between certain limits i, and I, of intensity of star light, and between certain limits t, and T, of exposure time. It has served very well to predict the diameter of over-exposed stars.

PHOTOGRAPHS OF SOLAR ECLIPSES.

The solar eclipse of January 1, 1889, occurred soon after the observatory was founded, and before suitable photographic instruments were available. Nevertheless, Mr. BARNARD contrived to take most capital negatives with some small cameras, and especially with an ordinary telescope of three inches aperture (reduced to 1¾ inches) and a focus of forty-nine inches. (Seed 26 plates were used, and exposures of 1, 3 and 4½ seconds.) The greatest pains were taken in focusing and in development, and his results are consequently of first-class excellence, and comparable with those obtained by much larger instruments, specially adapted for photography.

The Amateur Photographic Association of the Pacific Coast sent a large and competent party to the eclipse, under the direction of Mr. BURCKHALTER, and their negatives were kindly turned over to the Lick Observatory for discussion and publication. At this eclipse not only was the Corona thoroughly depicted, but the negatives of Mr. BARNARD of the Observatory, and of Messrs. LOWDEN and IRELAND of the A. P. A. P. C. (and many others) showed a new and

very remarkable extension to the outer Corona, never before photographed. As this "extension" was shown on several negatives taken by eleven persons at four different stations, there seems to be no question as to its veritable existence.

The expedition sent from the Lick Observatory at the cost of Hon. C. F. CROCKER, to observe the eclipse of December, 1889, was likewise fully successful. Both Mr. BURNHAM and Mr. SCHAEBERLE secured a number of capital photographs of the Corona. Their reports on this eclipse are not yet completed, and therefore I must content myself with a mere reference to them in this place. My own measures of their negatives are given in the table below.

Following the suggestion of Captain ABNEY and the example of Mr. W. H. PICKERING, of the Harvard College Observatory, the Lick Observatory plates were "standardized." That is, a portion of each plate was impressed with the light from a standard lamp, shining for a known time through a small hole at a known distance. The lamp produced small squares on the plates, and after development these squares were compared with the different parts of the Corona, in in order to measure the photographic brightness.

Assuming with Captain ABNEY that the stain on the plate is proportional to the exposure, I found the following results, which are compared with those of Mr. PICKERING in 1886:

	PICKERING—1886.	HOLDEN—Jan. 1889.	HOLDEN—Dec. 1889.
Intrinsic actinic brilliancy of the brightest parts of the Corona	0.031	0.079	0.029
Intrinsic actinic brilliancy of the polar rays (about)	....	0.053	0.016
Intrinsic actinic brilliancy of the sky near Corona	0.0007	0.0050	0.0009
Total actinic light of the Corona.....	37.	60.8	26.2
Total actinic light of the sky........	52000.	185625.	33412.
Ratio of total coronal to total sky light (actinic)	1 to 1400	1 to 3043	1 to 1285
Ratio of intrinsic brilliancy of the brightest parts of the Corona to that of the sky (actinic)...............	44 to 1	16 to 1	32 to 1
Intrinsic actinic brilliancy of the sky at 1° from the sun in daylight (average)	40.	....	....
Intrinsic actinic brilliancy of the full moon	1.66	....	....
Total actinic light of the full moon (SD = 16'.75)..................	1461.5	....	....
Intrinsic actinic brilliancy of sky within 5° of the full moon	0.000064	....	....
Magnitude of the faintest star shown on the eclipse photographs........	....	2.3	....

From this table (Column II) it appears that the polar rays are about eleven times as bright as the sky; and that the brightest parts of the Corona are one and one-half times as bright as the polar rays. Hence these are usually masked when they are projected upon the bright wings.

The intrinsic brilliancy of sunlight *plus* Corona (40.08) is $\frac{1}{100}$ part more than the brilliancy of the ordinary daylight 1° from the sun (40.0). Hence it would seem that the Corona (which has a continuous spectrum) can never be photographed in full daylight on our present plates.

As the planet *Vulcan* (?) (if any such planet exists) is not brighter than sixth magnitude, it follows that we cannot hope to photograph it on our present plates.

The corresponding results from the eclipse of December 21, 1889, are given in Column III. For reasons which I have given elsewhere I think the results in Column II are to be preferred to those in Columns I and III in spite of their agreement.

Photographs of the Moon.

Our first experiments in photography with the large telescope were made by Mr. Burnham, on the moon. As no suitable shutter was then available, the aperture was reduced to twelve and eight inches to increase the exposure time.

The best of these experimental pictures are very fine. Enlargements of them have been made on glass by Mr. Barnard, and I have been able to locate the minutest details of structure on these positives. Parallel walls on the moon, whose tops are no more than two hundred yards or so in width, and which are not more than 1,000 to 1,200 yards apart, are plainly visible.

In the examination of such pictures there is an immense advantage in using a positive copy on glass (which presents the different features in their natural lustre) rather than the original negative. The same thing is true of pictures of solar eclipses.

In certain negatives many details can be brought out by enlargement, or by reductions, that entirely escape notice on the originals.

Photographs of the Milky Way.

Mr. Barnard made some experiments in this direction in 1889, which promise the most satisfactory results. The instrument used was a five-inch portrait lens, and the exposures were 180 to 240 minutes.

It is proposed to photograph the whole of the Milky Way on one scale and with one exposure in this manner.

Photographs of Nebulæ and Comets.

Very little has yet been done here in these important fields. A few nebulæ have been photographed for experiment, with good results. Mr. Barnard photographed Davidson's comet, with a portrait lens and an exposure of ninety minutes. I have compared the brightness of the comet with that of the stain on the same plate derived from the light of a standard lamp shining for a known time on the film. If the conclusion of Capt. Abney, namely, that the stain on the plate is proportional to the time, is correct, then it followed that the comet was 10,000,000 times fainter than the full moon, area for area, and that it was 500,000 times fainter than the brightest parts of the Corona of January 1, 1889. The sky near the full moon is also, on the same hypothesis, 400 times more bright (photographically) than the comet, and 4,000 times more bright than the dark night sky.

Mr. Barnard's photographs of the nebula of *Andromeda*, with a portrait lens, are highly interesting and important, but we have as yet obtained no pictures of nebulæ which are as striking as the wonderfully fine impressions of the *Merope* nebula, of that in *Andromeda*, or of the great nebula in *Orion*, made by Messrs. Henry, Roberts and Common, and by the Harvard College Observatory.

The excellence of the great telescope will not be shown by extremely great extension of faint nebulæ, but rather by the very large scale on which these objects are taken. It has its own appropriate field, and within that field it promises admirable results. Many vexatious hindrances have occurred in making this great instrument ready for photographic use, but it is hoped that during the summer of 1890 it may be in full activity.

ON THE CHROMATIC ABERRATION OF THE THIRTY-SIX-INCH REFRACTOR OF THE LICK OBSERVATORY.

By James E. Keeler.

During the summer of 1889, while engaged in spectroscopic work with the thirty-six-inch equatorial, I made a number of rough determinations of the position of the focus of the object-glass for different colors, as an aid in adjusting the spectroscope. Since then I have repeated the measurements more carefully, and at a sufficient number of places in the spectrum to give an accurate determination of the "color curve" of the objective. The peculiarities of every very large or otherwise remarkable telescope are interesting, and even important, in view of their bearing on the future development of instrumental astronomy, and I have therefore arranged the results of the above-mentioned observations in a convenient form for reference and given them in the accompanying tables.

The method of studying the chromatic aberration of a telescope by means of a spectroscope, is sufficiently familiar to astronomers and physicists,* but it is not explained in the text-books, and no apology seems to be required for giving a short description of it here.

An achromatic object-glass is popularly supposed to bring light of all colors to the same focus, and this assumption is also made in the ordinary formulæ for lenses, which deal with first approximations only. It is, however, so far from being strictly true, that in very large telescopes the error is a source of considerable annoyance, and opticians have sought to diminish the false color of the image by giving the object-glass an unusually great focal length—thus reverting to the practice of the sixteenth century astronomers, who were acquainted with no other method for reducing the chromatic aberrations of their single object-glasses. In the thirty-six-inch equatorial of the Lick Observatory the difference of focal length for different colors amounts to several *inches;* nevertheless, it will be shown that this great range is not proportionally greater than in small telescopes, and is as small as the nature of the materials from which the object-glass is constructed will permit.

If a small spectroscope, having so low a dispersion that the whole

* It is due to Prof. H. C. Vogel, and is described by him in *Berichte der k. Akademie der Wissenschaften zu Berlin*, 29 April, 1880. There is also an excellent though short account in Dr. Gill's article, "Telescope," in the last edition of the *Encyclopædia Britannica*.

spectrum is within the limits of the field of view, is adjusted in the axis of a great telescope so that its slit is in the principal focal plane of the objective, and the telescope is directed to a star, the spectrum of the latter will not be a mere colored line of light, as it would be if the star image were formed by a reflector, but a curious spindle-shaped surface, somewhat resembling the outline formed by a thin vibrating rod with two fixed nodes. The breadth of the spectrum at any place is the diameter of the cone of rays having that particular wave-length, at its intersection by the plane of the slit, and if measured with a micrometer at different parts of the spectrum would give the transverse chromatic aberration in a known plane, and by a simple computation the axial aberration. A simpler method is, however, available. At the two "nodes," or points where the breadth of the spectrum is reduced to zero, rays having the wave-lengths of those parts of the spectrum come to a focus accurately in the plane of the slit. If the spectroscope is moved in or out, by means of the focusing-screw of the great telescope, the "nodes" will travel along the spectrum, retaining always the significance just explained, and if the spectroscope is withdrawn beyond a certain limit, only one node will be visible. If the wave-length of the point in the spectrum at which a "node" falls can be determined, the focal plane for that wave-length is known, being the plane of the slit, and the reading of the draw-tube scale, if the telescope is provided with one, will be a record of its position. Readings should be taken with the nodes in a number of different positions.

A bright star, like *Vega*, with a spectrum of the first class, is an admirable object for observations of this kind, since the intensely black hydrogen lines form marks of known wave-length with which the nodes can be brought into coincidence, and they are, moreover, thickly and regularly distributed in the violet, when the observations are most difficult. Between the red and the blue there are no strong lines in the spectrum of such a star, and a star of another class, as *Arcturus*, may be used instead; or the wire of the eye-piece micrometer of the spectroscope (if it has one) may be set at any desired wave-length by the aid of a previously prepared table, and will answer the same purpose as a fixed line in the spectrum.

The position of the "principal focal plane," in the ordinary sense, *i. e.*, for white light, in this system of focal planes for different homogeneous rays, remains to be determined. It will evidently be a *compromise* plane, the position of which will vary slightly for different eyes, and with the nature of the object examined. If the spectro-

scope is provided with a diagonal eye-piece for viewing the slit from behind, the position of the visual focus is very readily determined by first focusing the eye-piece on the slit, and then adjusting the large draw-tube until the best image of a star is obtained. If a diagonal eye-piece is not provided, the prism may be removed, the view telescope brought in line with the collimator, so that the slit is viewed directly, and the observation made as before. The reading of the draw-tube gives the position of the principal focal plane. If the construction of the spectroscope is such that its telescopes can not be brought into line, the position of the visual focus must be determined with a positive eye-piece (the spectroscope being removed), and referred by measurement to the scale of the draw-tube.

In the large spectroscope of the Lick Observatory the collimator is movable in the direction of its axis through a range of four inches, and is provided with a scale. The slit is viewed from behind by a diagonal eye-piece, so that the observations are made with great facility.

The following table gives the mean of a number of determinations made partly with a small spectroscope attached to the draw-tube of the great telescope, and partly with the large spectroscope just referred to, the objectives of which are of Jena glass. In both cases the chromatic aberrations of the spectroscope lenses themselves are too small to appreciably affect the results:

LINE OR OBJECT.	λ	DISTANCE FROM F.
		In.
B	6870.	0.00
C	6563.	—0.24
D	5893.	—0.45
Minimum Focus.	5650. ±	—0.47
F	4861.	0.00
Hγ	4340.	+1.45
Hδ	4101.	+2.76
Visual Focus.	White.	—0.20

In the last column is given the distance of the focal plane for the stated wave-length from the focal plane for the F line; the positive sign meaning that the focus for the given line is longer than for F, the negative sign that it is shorter.

From these observations a formula can be deduced expressing

empirically the focal length of the objective as a function of the wave-length of light, or, more conveniently, a curve may be drawn through points determined by the observations, with abscissæ representing wave-lengths, and ordinates focal distances, which will represent the same relation $F = \phi(\lambda)$ graphically, and this will be the "color curve" sought. It is evident that for a distinct visual image we must have $\frac{dF}{d\lambda} = 0$ for a value of λ corresponding to the *brightest* rays of the spectrum, and the table shows that this is the case, the minimum focus being in the greenish yellow. For a photographic lens we must have $\frac{dF}{d\lambda} = 0$ for a value of $\lambda =$ about 4300, or for those rays which most strongly affect a photographic plate. The determination of the color curve for the photographic objective of the Lick telescope presents many practical difficulties, the focus being within the tube at a place very difficult of access, and the form of this curve must be reserved for a future investigation.

The only other large telescope which (so far as I know) has had its color correction determined in this manner, is the twenty-seven-inch refractor of the Imperial Observatory of Vienna. Two color curves are given for this telescope by Professor VOGEL; one with the lenses of the objective separated by about four-fifths of an inch, the other with the lenses nearly in contact, the latter position being the more advantageous. Comparison of this curve with that for the Lick telescope, the ordinates being expressed not in inches, but in fractions of the mean focal length, shows that they are quite similar, the color curve for the Lick telescope rising somewhat more rapidly in the upper part of the spectrum.

The chromatic aberration of the Vienna equatorial was found by Professor VOGEL to be proportionally no greater than that of an excellent telescope, also by GRUBB, of about ten feet focal length, and hence, although the variation of focus with the color in these great instruments is surprising, we may conclude that it is as small as the nature of the materials at the command of the opticians will allow.

With the aid of the color curve it is easy to compute the radius (ρ) of the circle in which the cone of rays from the object glass intersects a given plane perpendicular to the axis of the telescope. Professor VOGEL has done this for the Vienna telescope, giving the radii for the principal FRAUNHOFER lines, the intersecting plane being supposed to pass through the focus for the F line. The following

table contains his results, as well as the same quantities for the thirty-six-inch refractor:

TABLE GIVING CIRCLES OF CHROMATIC ABERRATION FOR THE LICK OBSERVATORY AND VIENNA REFRACTORS.

	LICK TELESCOPE.		VIENNA TELESCOPE.	
LINE.	ρ IN INCHES.	ρ IN FRACTIONS OF FOCAL LENGTH.	ρ IN INCHES.	ρ IN FRACTIONS OF FOCAL LENGTH.
B	0.0118	.000017	0.0069	.000017
C	0.0055	.000008	0.0039	.000010
D	0.0000	.000000	0.0000	.000000
b	0.0031	.000005	0.0020	.000005
F	0.0118	.000017	0.0082	.000020
G	0.0530	.000078	0.0343	.000084
g	0.0655	.000096	0.0434	.000106

From this table it appears that the chromatic aberration of the thirty-six-inch refractor is smaller than that of the Vienna telescope. Its superiority in this respect does not, however, arise from a better adaptation of the optical parts, but is almost wholly due to the greater ratio of focal length to aperture (19 : 1 for the thirty-six-inch telescope and 15.3 : 1 for the Vienna telescope), the axial chromatic aberration being nearly the same in both.

The great difference of focus for rays of different colors with a large telescope is, as pointed out by Professor VOGEL, particularly embarrassing in spectroscopic work, only a small part of the spectrum being distinctly visible at one time. It also gives rise to some curious phenomena in ordinary visual observation. With the thirty-six-inch refractor, a planetary nebula and its stellar nucleus cannot be seen distinctly at the same time, the change of focus necessary being particularly noticeable if the nebula shows well-marked structural details, as for example the nebula (H IV 37) in *Draco.** I have sometimes been able to discriminate between a small star and a faint condensation of nebulosity in such an object by merely noting the reading of the draw-tube necessary for distinct vision, the telescope itself thus serving as a spectroscope. Stars of the WOLF-RAYET class, which emit light of (roughly speaking) only two definite colors, yellow and blue, present a peculiar appearance in the telescope,

* See *Monthly Notices* R. A. S., Vol. 48, p. 388, *et seq.* The change of visual focus required in this case is $\frac{44}{100}$ of an inch, or $\frac{1}{1600}$ of the focal length.

having two distinct foci separated by about half an inch, and, if bright enough, can be distinguished from ordinary stars merely by the aspect of the image. The visibility of planetary details differing greatly in color from the general surface tint, would doubtless be much affected by the same peculiarity of large telescopes. Thus, a fine blue line on the surface of *Jupiter* would be spread out into a diffuse band of considerable width at the visual focus, and, if faint, would certainly escape detection. Such differences of focus have been noticed in making drawings of *Mars* during the opposition of 1890. This is a subject of importance, and one which has as yet received little attention.

ARE THE PLANETS HABITABLE?

A Lecture delivered before the Catholic University of America, by Rev. George M. Searle.

Having completed our survey of the planetary system in which we live, a question naturally occurs to us, which has occurred to every inquiring mind since the real dimensions of the orbs belonging to it were known. To the great majority of mankind it is, and is rightly, a question of greater interest than any one with which mathematics or physics has to deal; of greater interest, since life is a much higher and nobler thing than machinery, and the spiritual far above the material. This question is, "Are these planets which, like our earth, move in their appointed paths around the sun, and on which there is certainly ample room for a population far greater than what our globe could support, actually inhabited by beings in any way like ourselves?"

Almost every astronomer has probably been asked what his views are on this question, and whether his science has anything to tell us about it. At each successive increase in the size of telescopes, men vaguely hope that with the new optical power it may be possible to discover some signs of sentient, and perhaps even of intelligent, life in the celestial worlds. "How much does this telescope *magnify?*" is always the interesting question to the popular mind. The professional astronomer perhaps is not looking so much for that. He wants to get more light; to see and to delineate faint nebulæ, to follow a comet as far as he can into the darkness of space, in order

to determine its orbit as well as possible; but the world in general has comparatively little sympathy with him in this. The discovery of one intelligent being outside this planet of ours would be more interesting to most men here than all the comets which ever have been, or ever will be seen.

Is it then possible that the power of telescopes will at any time be so increased that any discovery of this kind can be made? That is what people would like to know. Let us answer this question in the first place.

The moon is our nearest neighbor. If we can magnify enough to see an object the size of a man on any of the planetary orbs, we must first be able to see such an object on the moon. Is it possible to obtain a magnifying power sufficient for this?

It is possible, we answer, to have such a magnifying power; but the difficulty is to avail ourselves of such a power when we have got it. The great and turbulent sea of atmosphere which lies above us, is a seemingly insuperable difficulty. To some extent, of course, we can get free from this by placing our telescope on some high mountain; but there is no mountain high enough to place us altogether out of the atmosphere, and if there were one, we could not live or carry a telescope there. At the highest point at which observations would be possible, which probably would be a good deal below the summit of the Himalayas, enough air still would remain above us to prevent our using a power high enough to discern men like ourselves on the face of our satellite. The tremulousness and waviness produced in the telescopic image by the air, which is, of course, increased the more we magnify, would hopelessly obscure outlines so delicate as those here concerned, and make of such small points a simply invisible blur.

Even for the moon, then, the direct discovery of animal life by increased optical power, would seem to be a dream which will never be realized. The difficulty, of course, is immensely increased for any other celestial object. No other planet comes nearer to us than about one hundred times the moon's distance; and, moreover, in examining them, we should have to contend with the confusion of outlines coming from their atmospheres as well as from our own.

We may then as well give up hope of trying to answer the question, "Are the planets inhabited?" as one which never will be solved for us in this world by any natural means; and fall back on another, on which science, certainly, can give us some light, namely: "Are they *habitable;* are the physical conditions such in them, so far as

we can ascertain, that the life of man or of any highly organized animal, could there subsist?"

Now, I say the "planets"; for it seems to me that we may as well put the great central body of our system, the sun itself, out of the question. From what has been said regarding it in previous lectures, I think it is pretty clear that the surface at least of this enormous globe is in such a state as to make it absolutely impossible for us to conceive of any organized life existing there. It is true that we do not know exactly how much complexity of structure is required in matter as a basis of life; but we can hardly consider life in the proper sense as belonging to a chemical molecule, and everything would indicate that on the surface of the sun matter is reduced to its simply chemical or molecular state. Any structures or organisms which we call alive, would instantly be destroyed in that intense flame; even inanimate shapes, like those of crystals, would not survive its action for a moment.

But may there not be a cooler region below the sun's surface, protected in some way from the intense heat of the exterior? Such a theory was entertained in the last century and even in this; but it is pretty safe to say that no one now would hold it. That it should have held its ground so long is due perhaps in great measure to, the authority of Sir WM. HERSCHEL. I do not think it was ever satisfactorily explained just how the interior was protected from the immense radiation of its envelope; certainly, it is hard for us to see nowadays, knowing as we do the radiating power of the surface (10,000 horse-power per square foot, you remember, we found it to be) how such a blaze as this could even be supposed to be cut off from any point within. To suggest a cool place in the interior of the sun is much as if one should advise a person suffering from the heat of a furnace to wrap himself up well, and take a seat inside. Moreover, we know from spectroscopic indications now, particularly from those of oxygen in the sun, that the further in we go, the hotter it gets; and this also would follow from the only theory which can reasonably account for the formation of the sun, and the maintenance of its heat—that of HELMHOLTZ, previously mentioned.

We may pretty certainly say, then, that in any common-sense way of using the word, the sun is not habitable. Absolutely speaking, of course, all space is habitable; there is no conclusive reason why an organized being should require nutriment or air, and hence an animal might be conceived as being launched into space as a planet on his own account. But what we mean by a place being habitable is, that

it should furnish the requisites and conveniences belonging to a life similar in its principal features to that with which we are acquainted. It is not a thing which can be strictly defined; nevertheless, we know well enough for practical purposes, what we are talking about; and we know that such a place as this empty space is not "habitable."

From the consideration of the sun we will pass to that of the next most conspicuous object to us in the planetary system; that is to say, the moon. I have already expressed in a previous lecture the views generally entertained by astronomers about the moon. It is pretty certain that the side of it which we see offers nothing in the way of a convenience of life except mere standing-room. There is hardly a doubt that its surface consists simply of bare rock, unvaried by water, soil, or any kind of vegetation; that if there be any atmosphere upon it, it is so excessively rarefied as to be, for purposes of life, practically equivalent to none.

As to the other side, of course, we can say nothing positively. It may perhaps in some way be different from this. But taking the ordinary and (to say the least) very probable view as to the method of formation of the planetary masses, by cooling from a liquid condition, it is hard to see how there could possibly be any considerable difference of shape or of density between the half of the lunar sphere which is turned towards us, and that which is turned away. And unless there be such a difference, the other side must be as destitute of atmosphere as this; and if of atmosphere, of water as well; for the water or other fluid, if existing in any quantity, would form an atmosphere, if none previously existed.

The moon then hardly seems to present the condition required for what we should call a habitable planet; though it fails in a very different way from the sun. The moon is dead; the sun is too much alive. The moon may have been habitable and inhabited once; the sun may be in the future.

So far, our survey has not been very encouraging. But we have not yet considered the planets properly so-called.

In considering them from this point of view, let us proceed in the contrary order to that which we followed in describing them in detail. Let us start at the outer limit, with the great twin planets, as we may call them, on account of their great similarity, widely separated in space as they are, namely *Uranus* and *Neptune*.

These would perhaps generally be imagined as very cheerless habitations for intelligent beings, on account of their distance from the sun, and the comparatively small amount of light and heat which

that great central fire sends to them, if that which the earth receives be taken as the standard. Particularly would this impress us in the case of *Neptune*. Its distance from the sun is about thirty times ours, and, according to the oft-repeated law of the inverse squares of the distances, the light and heat which it gets from the sun is only one nine-hundredth part of that which we receive. But let us not give up the matter as hopeless on this account. One nine-hundredth part of sunlight is not such a faint illumination after all. It is nearly 700 times the light of the full moon, and indeed equal to that given by a large electric arc-lamp at a distance of a few feet. There would be no difficulty about reading by means of it; it would be quite sufficient for all the ordinary practical purposes for which sunlight is used here. And then there is another consideration which is of very great weight.

It is this: You know that, as I have said, what astronomers increase the size of telescopes for is to gather more light, rather than to get greater magnifying power. A telescope of two inches diameter, or aperture, as it is technically called, will give four times as much light as one of only one inch; one of ten inches will give twenty-five times as much as the two-inch, or a hundred times as much as the one-inch. The great Lick telescope, of three feet aperture, makes a star look about thirteen hundred times as bright as a one-inch spy-glass, and enables us to see stars about twenty thousand times fainter than any which can be seen with the naked eye. And the same rule would hold for the eye itself. If we should increase the size of the pupil of the eye, we should see fainter objects than we do now; and we indeed actually do this when we go from bright light into a dark room. We can easily see how the pupil dilates to accommodate itself to reduced light, by simply examining another person's eye in these changed conditions, or our own before a looking-glass. The eye of a cat changes much more. If the retina of the cat's eye is as sensitive as our own, she must habitually see stars five or six times fainter than any which we can discern without a glass, and the heavens must present to her a magnificent appearance, if she cares to look at them. Probably she actually uses this increased light rather to discover mice than stars; but her astronomical opportunities are there all the same, though she may not avail herself of them.

It is true that this increased light is obtained in the eye at some sacrifice of definition, or sharpness of vision in detail; but still an inhabitant of *Neptune* might have a good deal larger pupil than ours in proportion to the size of his eye than ours. And then again, there

is no reason why the retina itself should not be made much more sensitive to light than ours; and here we have an increase which has no limit, so far as we can tell. It would be an injury to us to have our optic nerve more sensitive; the strong sunlight to which we are exposed would hurt us. But there is no reason why the Neptunians should not have what would be a benefit to them.

The whole question, then, of light in the solar system is one of little consequence; eyes could easily in any planet be such as to suit the exigencies of the case.

With regard to heat, the question is a little more difficult, but not very much. If we should assume that the 500 degrees Fahrenheit by which our temperature here is raised above that of space are simply due to our distance from the sun, and that *Neptune* could only have one nine-hundredth part of that, of course the temperature there would practically be that of space itself, or 460 below the Fahrenheit zero. But we know that in fact the genial warmth of the earth is in a great measure due to its atmospheric garment or blanket; and we cannot be at all sure that an atmosphere may not exist on *Neptune* which may make the absorption so much greater than the radiation that an equality between the two would not be reached before the planet had accumulated from its scanty solar supply enough to make its temperature equal to ours.

And, besides, there is no certainty that these great outer planets may not still retain a great deal of their own intrinsic heat; that they may yet be warm enough, even on the surface, to act as a source of heat to their inhabitants. Indeed, the danger here is rather that they are too hot than too cold. Yes, that is the trouble with all the great outer planets, with *Jupiter* and *Saturn*, as well as *Uranus* and *Neptune*, as we shall shortly see. As far as atmosphere is concerned, the spectroscope would indicate rather a dense one on both *Uranus* and *Neptune*, and of the same character on each. *Uranus* shows belts on its surface similar to those seen on *Jupiter*, but we cannot be sure that this indicates a similar constitution in the two planets. On the whole, we may say that there is quite what we may call a probability that *Uranus* and *Neptune* are in a habitable condition; the probability is, however, as we may say, rather negative than positive; we cannot give any certain reason why they should not be; but there are really no positive indications to show that they are fit to be the abode of life. The arguments against habitability become much stronger in the case of the two giants of the planetary system, *Saturn* and *Jupiter*, which come next in order

as we proceed toward the sun. The brilliancy of *Jupiter's* surface, and the rapidity of the changes which we see there, exceeding what the moderate light and heat which it receives from the sun would be likely to produce, seem to be quite strong arguments that it is still in a condition to emit light and heat to a considerable extent on its own account; and, indeed, that its temperature is still sufficient to keep it in a fluid state. If its surface be indeed in the condition of molten metal, it certainly becomes uninhabitable in the common-sense view of the subject; for in melted metal no organism composed of ordinary chemical elements could possibly subsist.

These arguments apply with somewhat diminished force to *Saturn*. Another, however, which may perhaps be derived from the lightness or small density of all the four great exterior planets of which we have been speaking, is strongest in the case of this one. This lightness may indicate that they have not yet shrunk to their proper dimensions; for it seems reasonable enough to suppose that the chemical constituents throughout the solar system are the same; that all the planets are chips out of the same block; and that when all reduced to the physical state of the earth they would have about the same density. But this does not seem to amount to much; for though it holds well enough in the cases of *Mars* and *Venus*, it notably fails in that of *Mercury*, if the determinations of the mass of that planet can be considered as trustworthy. The density of *Mercury* would appear, it will be remembered, to be twice that of the earth; which would prove most undoubtedly that it was made of decidedly heavier materials, unless we maintain that it is very much more solidified than the earth; which would seem to be improbable. When a planet has once become, like the earth, solid on the surface, no further perceptible shrinkage is possible except by a complete breaking up of the crust, which could hardly result except from a collision.

But to return to the great planets of which we have been speaking. I think few, if any, astronomers believe them to be habitable in their present condition; for, though the case is more doubtful for *Uranus* and *Neptune*, still they have, in their general features, so much resemblance to *Jupiter* and *Saturn*, that it is usually presumed that they are in the same state. But no one could pretend to be certain with regard to the matter.

Before we leave this portion of our system, however, we must not omit a part of it which is eminently worth considering with reference to the present question. I mean the numerous satellites, which are such a striking feature in it.

Let us consider specially those of *Jupiter*, about which we know the most. The four moons of *Jupiter* are all quite considerable bodies, ranging in size from that of our moon to that of the planet *Mars*. There is plenty of room on them for a very large population; the surface of the largest does not fall far short of that of the land part of our own globe. There is no reason why they should not be in the same general physical state as the earth is; we have already seen that, as far as light and heat are concerned, they may be considered as amply provided; perhaps, indeed, even better than we; for the great planet itself, round which they circulate, would probably serve as a much better luminary by night than our own moon, and may very probably contribute not a little to keeping them comfortably warm, if it is indeed still in a melted and glowing condition. We may well believe that it is indeed a second sun to them, and if the satellites of *Jupiter* keep, like our own moon, the same side always turned toward the primary planet, that favored side would enjoy a continual warmth, which might indeed be excessive.

Similar remarks may, of course, be made of all the other satellites which we find in this great region, revolving round *Saturn*, *Uranus* and *Neptune*. Much has been said of the splendor of the Saturnian sky as seen from the planet itself, with the great ring arching over the heavens and the satellites circling along it. It is far more likely that, if this splendor is seen at all, it is from the satellites, from which, especially from *Japetus*, the most remote, whose orbit lies outside of the plane of the ring, a most magnificent view of the noble planet, with its rings and the other satellites, could be had. *Saturn* from *Japetus* would look as it does to us with a magnifying power of about 350 diameters; or, to use another illustration, the ball of the planet would look about three and a half times the diameter of the moon, and the rings nearly nine times that diameter.

We come next, in our inward course, to the planet *Mars*. Here, for the first time, we begin to see positive signs, instead of mere negative possibilities, of what we have been looking for.

We have noticed, as we passed this planet on our way outward from the sun, the similarity of its surface to that of the earth, the permanent configurations on it of what we have a good right to assume to be land and water. We have seen its polar ice-caps, its green seas, and red earth; and we know that it has an atmosphere which, though not as dense as our own, is still enough, as it would seem, for life. We know that it has a day almost exactly the same as ours, and not only this, but seasons substantially like our own, as far as the vary-

ing angle is concerned at which the sun's rays strike its surface, though it is true that these are a good deal interfered with by the considerable variation in the sun's heat, depending on the eccentricity of its orbit; still this would not amount to so very much. In this latitude, for instance, on the earth, we receive more than three times the heat from the sun in one day in the middle of June than we get in the middle of December, on any given area, say a square mile or a square yard, owing to the combined influence of the greater height of the sun above the horizon and the greater length of the daylight. About the same would be the case in the same latitude on *Mars*. The effect of the eccentricity would be quite considerable, making the sun's heat once and a half as great at the nearest point as at the farthest; still, if we can sustain the three-fold multiplication, a half as much again might be added, without the variation becoming intolerable. Moreover, this great variation would only occur, when the summer solstice of one of the hemispheres coincided with the point of nearest approach to the sun. During half the time, the eccentricity would tend to moderate, instead of to accentuate, the seasons, as it does with us here in the northern hemisphere now.

Mars is certainly the most favorable case for those who would believe the planets to be habitable. It really seems that it might be inhabited by men like ourselves. As remarked on a previous occasion, its climate seems, from the small size of the polar ice-caps, to be warmer than that of the earth, in spite of its greater distance from the sun.

As to *Venus* and *Mercury*, we can hardly form any decided opinion. They seem to be surrounded by dense, cloudy atmospheres, which may tend, in a great measure, to keep off the intense heat of the sun. A rather singular thing has lately been observed, or, at least, thought to be observed, by SCHIAPARELLI, with regard to *Mercury*; that is, that some markings on it seem to indicate that its period of rotation round its axis is the same as that of its revolution round the sun; or, in other words, that it acts as our moon does, keeping always the same face toward the center round which it revolves. This would seem to be borne out by the white spot on the black disc of the planet, which has been reported by various observers as regularly visible at the time of its transits across the sun's face. If this white spot is a real object, it would seem that it is always turned away from the sun. If this can be accepted, it would be, of course, to some extent, an argument against the habitability of *Mercury*; as its inhabitants would be deprived of the vicissitude of day and

night, and the side turned constantly toward the sun would probably, in spite of everything, become uncomfortably warm.

Now that we have—though quite hurriedly—completed our consideration of the planets as to their suitableness for habitation, what answer shall we give to the question with which we started? Before giving it, another reflection must be made, which will brighten the prospect a good deal for those who would fain believe all these magnificent orbs to be the abode of life like ours.

It is this: Will it not suffice to satisfy the minds of those who cannot believe that these great globes, similar in so many respects to ours, can be tenantless, to hold that they are habited for a portion, though not for the whole, of their history? For myself, I do not feel the craving for the plurality of worlds, as it is called, which seems to be general. I must confess that I have never been able, personally, to feel the force of the argument which strikes most minds so powerfully, that these habitations could not have been made by their Creator except to be actually inhabited. The mere size and mass of an object seems to me to amount to little. *Jupiter* itself, or *Saturn*, with its beautiful ring and satellite system, simply as a mass of matter or a mechanical construction, is a far less noble creation of God than a single human soul; nor does it seem to me that the mere size of these planets makes them much more remarkable, or requires more reason for their formation, than if they were only a few feet in diameter. The technical study of astronomy, no doubt, has the effect of reducing the impression made by mere magnitude on the mind; whether this is a delusion or the removal of a delusion, of course, I cannot say. That the mere size of a body itself does not require inhabitants for it, seems plain from the generally-confessed impossibility of inhabiting the sun, the surface of which far exceeds that of all the planets put together; that is to say, that it does not require them at every moment; but it may be, if you will, that it does require that at some time or other it should be used for such a purpose. The general belief is, we may say, an argument for the fact.

And, of course, the argument for the plurality of worlds is strengthened, if, beside size or standing-room, as we may say, we see some other conditions indicating conveniences for life, though they be imperfect or incomplete. If we see a house with only its framework up, we say, "Nobody lives there now, but it is being built for some one"; and if we see a house in ruins, we say, "Somebody lived there once."

Now, this is certainly very plausible; and I think that the history of our own earth, so far as it can be learned from science, increases the probability of the opinion that the planets, and perhaps even the sun itself, were made to be inhabited at some time or other. The teaching of geology is that our own earth was for a long time uninhabitable, that it subsequently became fitted to be the abode of the inferior and simpler forms of life, and finally became ready for the reception of man; and we can hardly shut our eyes, either, to the scientific conclusion, that from the operation of natural causes alone, it would at some time in the distant future become uninhabitable again, though in a different way; that it would become, simply from the changes which must come from the gradual progress of cooling necessarily going on in the solar system, no longer a building which its Creator is forming, but a cold and desolate ruin like the moon.

The history of this earth is probably the history of the other planets, if they are to be allowed to develop in a natural way. Some, like the moon, seem to have passed further along the road than our own planet. This is probably the case with *Mars*, the most habitable in appearance of them all. As a rule, of course, the smaller a planet is, other things being equal, the more rapidly it will cool from its originally incandescent state; *Mars* then should be older,—that is, have passed through more of its successive changes, than we. It looks so, besides. The seas seem to be drying up, the air thinning away. On the other hand, the great superior planets, *Jupiter*, *Saturn*, *Uranus* and *Neptune* are young, and have the best part of their life before them.

What portion of the total life of a planet is that in which it becomes habitable by beings like ourselves, we cannot very well determine. If we accept the estimates of geology, the time that the human race has been here is a very small part of our world's history. But how much longer this earth would naturally remain a possible residence for us we cannot say with accuracy. It would seem probable, however, that the period in which all the necessary conditions of life would simultaneously exist, can hardly be a very considerable part of the whole. The inhabitants of a planet in the stage of decadence from its most perfect state could, no doubt, on the principle of the "survival of the fittest," accommodate themselves to their more unfavorable circumstances for a good while; but the time would come when the struggle would have to be abandoned.

If it is true that the period of habitability by the high organisms

is a small part of a planet's life, obviously the chance is small for any planet in particular of its being in that period now or at any particular time. We must say that it probably is not, unless we have, as in the case of *Mars*, some positive indications that it is. So far as we can trust such positive indications, *Venus* and *Mercury* are approaching that part of their life that the earth is in at present; the earth seems at one time to have had the very dense and vaporous atmosphere that apparently surrounds them now.

To sum up now briefly, the results to which our examination has led us: In the first place, our observations should probably be modified by the very plausible theory, now generally adopted, that all the bodies of our system, sun and planets, have passed and are passing through a series of changes, beginning with a state of great heat and expansion, in which and for a long time no life is possible on their surfaces, and in a great part of which indeed, as in the case of the sun at present, they can hardly be said to have a surface at all. As the changes due to the gradual cooling and contraction proceed, life in its simpler forms becomes possible, and in course of time a state is reached like that of this globe at present, in which the conditions for highly organized life are at their best.

Assuming this, the question of fact becomes, is there any other planet or satellite in the system in which this state of maximum habitability, if we may so call it, now exists? We can say with great confidence that it does not on *Jupiter* and *Saturn*; that the chances are much against it on *Uranus* and *Neptune*; that *Venus* and *Mercury* are probably still too young for it; but that there is a reasonable probability for it on *Mars*, though this planet seems to be passing into the decline, the steps of which we do not clearly understand, but of which we see perhaps the final result in the torn, scarred, and desolate surface of our own satellite. With regard to the satellites of the great planets, we have absolutely to suspend judgment. As the period of habitability is probably less than that of development, though of this we are far from certain, the chances are perhaps against any particular one of them being in that state just now; but as they number at least seventeen altogether, the probability that some one of them may be habitable is not so inconsiderable. As to the satellites of *Mars*, and the swarm of asteroids, they seem to be too small to retain an atmosphere sufficient for the support of beings like ourselves. If they had a course to run, it has probably been concluded long ago.

In speaking of the natural life and development of the planets,

we are, of course, looking at the matter merely from a scientific point of view. Of course, most Christians believe that long before the natural life of this earth would be concluded, it will suffer a final catastrophe which will at least close the history of the human race on it as it exists now. Such catastrophes may, of course, occur to any planet by natural as well as supernatural causes; by collision with some other body, for instance; or to the whole planetary system, by some large body striking on the sun. One thing which we may perhaps look forward to is a time when, after the death or destruction of all the planets, the sun itself ceasing to be a luminary and furnace for bodies circulating round it, may itself become the great seat and home of life. In theorizing on this point we have no past experience or history to guide us. We shall see as we go on to discuss the stellar systems that we have at least one case, perhaps more than one, of a body sun-like in dimensions, which has either ceased to give light, or never gave it. It is only in exceptional cases that we have any means of recognizing the existence of such bodies; they may be very numerous. Neither can we tell whether the other innumerable brilliant suns scattered through space have attendant planets like our own. But it would be strange if they had not. If any considerable proportion of them have, evidently the chance that there are other habitable worlds in the universe becomes very great.

ON HYPERBO-ELLIPTIC FUNCTIONS.

By Irving Stringham, Ph. D.

I.

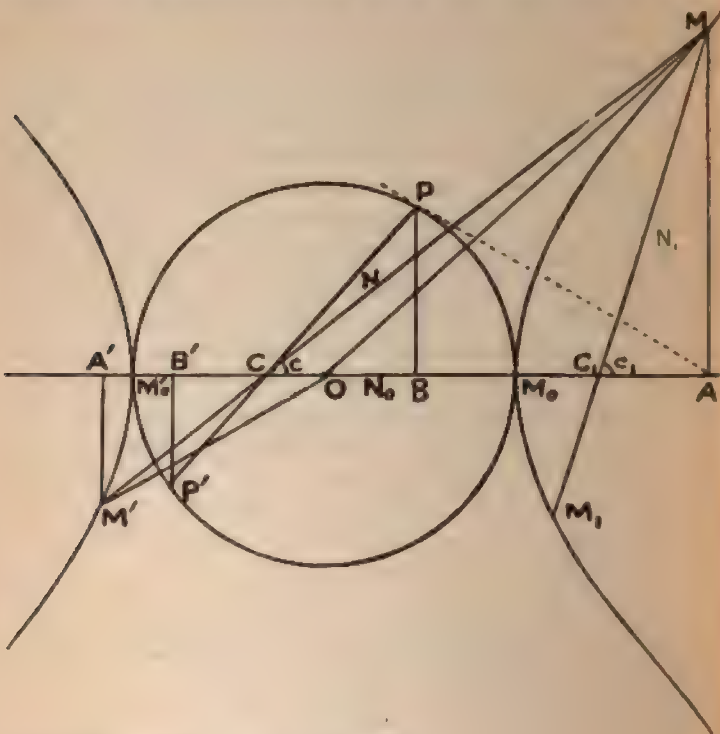
The geometrical definition of the Legendrian, or cyclo-elliptic functions by means of a circle, as given by the late M. Halphen in his *Traité des Fonctions Elliptiques*, t. I, p. 2, suggests an analogous construction for the equilateral hyperbola, through which what I venture to call the *hyperbo-elliptic functions* may in like manner be defined. M. Halphen's treatment is strictly geometrical, but the analytical form of presentation is better adapted to the analogous theory here sketched in outline.

GEOMETRICAL REPRESENTATION.

With $M_0' M_0$ as principal diameter, construct an equilateral hyperbola, as in the accompanying figure, and let

$$\overline{M_0' M_0} = 2R = 2\,\overline{OM_0}.$$

Through a fixed point C on the diameter draw the variable chord of the hyperbola $\overline{M' M}$ and from M and M' drop $\overline{MA}$ and $\overline{M'A'}$ per-



pendicular to $\overline{OA}$. Then we may write

$$\overline{OA} = R \cosh 2\phi, \qquad \overline{AM} = R \sinh 2\phi,$$
$$\overline{OA'} = R \cosh 2\phi', \qquad \overline{A'M'} = R \sinh 2\phi',$$

whence

$$\textit{sectorial area } OM_0 M = \tfrac{1}{2} R^2\, 2\phi = R^2 \phi,$$
$$\textit{sectorial area } OM_0' M' = \tfrac{1}{2} R^2\, 2\phi' = R^2 \phi'.$$

Writing $\overline{CO} = \delta$, the position of the point N on the chord MM' is defined by the equation

$$(1) \qquad CN = l \left\{ \frac{2(R+\delta)}{MM'} \right\}^{\frac{1}{2}} [\cosh 2(\phi + \phi')]^{\frac{3}{4}},$$

in which l is an arbitrary constant. Let N_0 be the position of N when CM coincides with CM_0, and let the sectorial area CN_0N be represented by $l^2 u$. Then since to every point M on the hyperbola there corresponds a unique position of N on the curve N_0N, u is a function of ϕ. Imitating the nomenclature and notation of the cyclo-elliptic functions, I call ϕ the hyperbolic amplitude of u and write

$$\phi = \text{hm } u.$$

This functional relation will be more explicitly determined by means of the differential equation

$$d\phi = \text{hm}' \, u \, du\,;$$

for if the angle N_0CN be denoted by c, the differential of the sectorial area CN_0N is

$$l^2 \, du = \tfrac{1}{2} \, \overline{CN}^2 \, dc,$$

and in order to find hm$'$ u it is only necessary to find the values of dc, MM' and $\cosh 2(\phi + \phi')$ in terms of ϕ and $d\phi$.

The following equations are evident from the figure:

$$(2) \quad \begin{aligned} MM' \sin c &= R\,(\sinh 2\phi + \sinh 2\phi') \\ &= 2R \sinh(\phi + \phi') \cosh(\phi - \phi'), \\ MM' \cos c &= R\,(\cosh 2\phi + \cosh 2\phi') \\ &= 2R \cosh(\phi + \phi') \cosh(\phi - \phi'), \end{aligned}$$

$$(3) \quad \begin{aligned} CM \sin c &= R \sinh 2\phi, \\ CM \cos c &= R \cosh 2\phi + \delta\,; \end{aligned}$$

$$(4) \qquad \therefore \quad \tan c = \tanh(\phi + \phi') = \frac{R \sinh 2\phi}{R \cosh 2\phi + \delta}.$$

From the last equation the other functions of $\phi + \phi'$, and also those of $\phi - \phi'$, are easily found to be

$$\sinh(\phi + \phi') = \frac{R \sinh 2\phi}{D}\,; \quad \cosh(\phi + \phi') = \frac{R \cosh 2\phi + \delta}{D}\,;$$

$$\sinh(\phi - \phi') = \frac{\delta \sinh 2\phi}{D}\,; \quad \cosh(\phi - \phi') = \frac{\delta \cosh 2\phi + R}{D},$$

where $\qquad D = \sqrt{R^2 + 2R\delta \cosh 2\phi + \delta^2}.$

Differentiating the several terms of equations (4) we have

$$\sec^2 c \, dc = \text{sech}^2(\phi + \phi') \, d(\phi + \phi') = \frac{2R\,(R + \delta \cosh 2\phi)}{(R \cosh 2\phi + \delta)^2} \, d\phi.$$

But from the same equations is also easily obtained

$$\sec^2 c = 1 + \tanh^2(\phi + \phi') = \frac{\cosh 2(\phi + \phi')}{\cosh^2(\phi + \phi')}\,;$$

hence
$$dc = \frac{d(\phi + \phi')}{\cosh 2(\phi + \phi')}$$
$$= \frac{2R(R + \delta \cosh 2\phi)\cosh^2(\phi + \phi')}{(R\cosh 2\phi + \delta)^2 \cosh 2(\phi + \phi')} d\phi$$
$$= \frac{2R(R + \delta\cosh 2\phi)}{D^2 \cosh 2(\phi + \phi')} d\phi;$$

and since equations (1) and (2) give
$$\overline{CN}^2 = l^2 \frac{2(R + \delta)[\cosh 2(\phi + \phi')]^{\frac{3}{2}}}{2R\cosh(\phi + \phi')\cosh(\phi - \phi')} \cos c$$
$$\therefore \quad \tfrac{1}{2}\overline{CN}^2 dc = l^2 \frac{(R + \delta)(R + \delta\cosh 2\phi)}{D^2 \cosh(\phi - \phi')} d\phi$$
$$= l^2 \frac{R + \delta}{D} d\phi = l^2 \frac{d\phi}{\sqrt{k^2 \sinh^2\phi + 1}},$$

where $k^2 = \dfrac{4R\delta}{(R + \delta)^2}$. Hence the differential equation connecting u and ϕ is

$$(5) \qquad du = \frac{d\phi}{\sqrt{k^2 \sinh^2\phi + 1}},$$

and
$$\text{hm}' u = \sqrt{k^2 \sinh^2\phi + 1}.$$

When the fixed point C lies upon the diameter $M_0' M_0$ *produced*, say at C_1 as represented in the figure, the chord MM_1 has its extremities upon the same branch of the hyperbola, the argument formerly represented by ϕ' is now to be regarded as negative, say $-\phi_1$, and the equation defining the locus of N_1 is

$$(6) \qquad C_1N_1 = l\left\{\frac{2(R + \delta_1)}{MM_1}\right\}^{\frac{1}{2}} [\cosh 2(\phi - \phi_1)]^{\frac{3}{4}},$$

where $\delta_1 = OC_1$.

The transformations that lead to the differential equation in ϕ and u differ but little from those of the preceding case, and I merely write down the successive results:

$$MM_1 \sin c_1 = R(\sinh 2\phi + \sinh 2\phi_1)$$
$$= 2R\sinh(\phi + \phi_1)\cosh(\phi - \phi_1),$$
$$MM_1 \cos c_1 = R(\cosh 2\phi_1 - \cosh 2\phi)$$
$$= -2R\sinh(\phi + \phi_1)\sinh(\phi - \phi_1);$$
$$C_1M_1 \sin c_1 = R\sinh 2\phi,$$
$$C_1M_1 \cos c_1 = R\cosh 2\phi - \delta_1;$$
$$\therefore \quad \tan c_1 = -\text{ctnh}(\phi - \phi_1) = \frac{R\sinh 2\phi}{R\cosh 2\phi - \delta_1}.$$

$$\sinh(\phi - \phi_1) = \frac{R \cosh 2\phi - \delta_1}{D_1}; \quad \cosh(\phi - \phi_1) = \frac{R \sinh 2\phi}{D_1};$$

$$\sinh(\phi + \phi_1) = \frac{\delta_1 \cosh 2\phi - R}{D_1}; \quad \cosh(\phi + \phi_1) = \frac{\delta_1 \sinh 2\phi}{D_1};$$

$$D_1 = \sqrt{-R^2 + 2R\delta_1 \cosh 2\phi - \delta_1^2}.$$

$$\tfrac{1}{2}\, \overline{C_1 N_1}^2\, dc = l^2 \frac{R + \delta_1}{D_1}\, d\phi - l^2 \frac{d\phi}{\sqrt{k_1^2 \cosh^2 \phi - 1}},$$

where $k_1^2 = \frac{4R\delta_1}{(R + \delta_1)^2}$. Representing this differential area by $l^2 du$ we have the differential equation

$$du = \frac{d\phi}{\sqrt{k_1^2 \cosh^2 \phi - 1}}. \tag{7}$$

Suppose a solution of this equation to be represented in symbolic form by

$$\phi = \text{co-hm}\, u,$$

then ϕ is to be regarded as the hyperbolic coamplitude of u,

$$d\phi = \text{co-hm}'\, u\, du$$

and

$$\text{co-hm}'\, u = \sqrt{k_1^2 \cosh^2 \phi - 1}.$$

Definitions.

Given u and ϕ as functions of each other through the differential equation

$$du = \frac{d\phi}{\sqrt{k^2 \sinh^2 \phi + 1}}$$

the hyperbo-elliptic functions are defined as follows:

$$\phi = \text{hm}\, u, \text{ (hyperbolic amplitude of } u\text{)},$$
$$\sinh \phi = \text{hs}\ u,$$
$$\cosh \phi = \text{hc}\ u,$$
$$\sqrt{k^2 \sinh^2 \phi + 1} = \text{hd}\ u;$$

or, by means of the figure, they are defined geometrically as follows:

$$\text{hs}\ u = \frac{AM + A'M'}{MM'} \sqrt{\sec 2c},$$

$$\text{hc}\ u = \frac{AA'}{MM'} \sqrt{\sec 2c},$$

$$\text{hd}^2\ u = \left\{\frac{R - \delta}{R + \delta}\right\}^2 + \frac{4R\delta}{(R + \delta)^2} \left\{\frac{AA'}{MM'}\right\}^2 \sec 2c,$$

where $$\sec 2c = \frac{(MM')^2}{(AA')^2 - (AM + A'M')^2}.$$

The above expression for $\mathrm{hd}^2\, u$ is readily obtained as the equivalent of $1 + k^2 \sinh^2 \phi$.

The following formulæ are immediate consequences of these definitions:

$$\mathrm{hc}^2\, u - \mathrm{hs}^2\, u = 1,$$
$$\mathrm{hd}^2\, u - k^2\, \mathrm{hs}^2\, u = 1;$$

$$d\, \mathrm{hm}\, u = \mathrm{hd}\, u\,.\,du,$$
$$d\, \mathrm{hs}\, u = \mathrm{hc}\, u\,.\,\mathrm{hd}\, u\,.\,du,$$
$$d\, \mathrm{hc}\, u = \mathrm{hs}\, u\,.\,\mathrm{hd}\, u\,.\,du,$$
$$d\, \mathrm{hd}\, u = k^2\, \mathrm{hs}\, u\,.\,\mathrm{hc}\, u\,.\,du.$$

It is evident that $\mathrm{hc}\, u$ and $\mathrm{hd}\, u$ are never numerically less than 1 and that

$$\mathrm{hm}\, 0 = 0, \qquad \mathrm{hc}\, 0 = 1,$$
$$\mathrm{hs}\, 0 = 0, \qquad \mathrm{hd}\, 0 = 1.$$

These equations are the analogues, line for line, of the following definitions and formulæ of the cyclo-elliptic functions, which I write down for comparison and reference.

If $$du = \frac{d\theta}{\sqrt{1 - k^2 \sin^2 \theta}},$$

then by definition $$\theta = \mathrm{am}\, u, \text{ (amplitude of } u),$$
$$\sin \theta = \mathrm{sn}\, u,$$
$$\cos \theta = \mathrm{cn}\, u,$$
$$\sqrt{1 - k^2 \sin^2 \theta} = \mathrm{dn}\, u;$$

or, geometrically, by means of the figure, these definitions are

$$\mathrm{sn}\, u = \frac{PB + P'B'}{PP'},$$

$$\mathrm{cn}\, u = \frac{BB'}{PP'},$$

$$\mathrm{dn}^2\, u = \left\{\frac{R + \delta}{R - \delta}\right\}^2 + \frac{4R\delta}{(R + \delta)^2} \left\{\frac{BB'}{PP'}\right\}^2;$$

while $2\theta = \text{angle } POB$, $2\theta' = \text{angle } P'OB'$, $\theta + \theta' = \text{angle } PCB$ and the locus of the point N, on the chord PP', is defined by

$$CN = l \left\{\frac{2(R + \delta)}{PP'}\right\}^{\frac{1}{2}}.$$

Then $$\operatorname{sn}^2 u + \operatorname{cn}^2 u = 1,$$
$$\operatorname{dn}^2 u + k^2 \operatorname{sn}^2 u = 1\,;$$
and
$$d \operatorname{am} u = \operatorname{dn} u \,.\, du,$$
$$d \operatorname{sn} u = \operatorname{cn} u \,.\, \operatorname{dn} u \,.\, du,$$
$$d \operatorname{cn} u = -\operatorname{sn} u \,.\, \operatorname{dn} u \,.\, du,$$
$$d \operatorname{dn} u = -k^2 \operatorname{sn} u \,.\, \operatorname{cn} u \,.\, du.$$

Relations between Hyperbo-Elliptic and Cyclo-Elliptic Functions.

If in the differential expression $d\phi/\sqrt{1 - k^2 \sin^2 \phi}$ the substitution $\phi = -i\chi$ be made, the result is

$$du = \frac{d\phi}{\sqrt{1 - k^2 \sin^2 \phi}} = \frac{1}{i} \frac{d\chi}{\sqrt{k^2 \sinh^2 \chi + 1}}\,;$$

hence

$$d\,iu = \frac{d\chi}{\sqrt{k^2 \sinh^2 \chi + 1}} = \frac{d\,i\phi}{\sqrt{k^2 \sinh^2 i\phi + 1}},$$

and therefore

$$i\phi = \operatorname{hm} iu = i \operatorname{am} u,$$
$$\operatorname{hs} iu = \sinh i\phi = i \sin \phi = i \operatorname{sn} u,$$
$$\operatorname{hc} iu = \cosh i\phi = \cos \phi = \operatorname{cn} u,$$
$$\operatorname{hd} iu = \sqrt{-k^2 \operatorname{sn}^2 u + 1} = \sqrt{1 - k^2 \sin^2 \phi} = \operatorname{dn} u\,;$$

or, changing u into iu, these become

$$i \operatorname{am} iu = \operatorname{hm} (-u) = -\operatorname{hm} u,$$
$$i \operatorname{sn} iu = \operatorname{hs} (-u) = -\operatorname{hs} u,$$
$$\operatorname{cn} iu = \operatorname{hc} (-u) = \operatorname{hc} u,$$
$$\operatorname{dn} iu = \operatorname{dn} (-u) = \operatorname{dn} u,$$

If in the same differential expression the substitution $\phi = \frac{\pi}{2} - i\psi$ be made, the result is

$$du = \frac{d\phi}{\sqrt{1 - k^2 \sin^2 \phi}} = \frac{d\psi}{\sqrt{k^2 \cosh^2 \psi - 1}},$$

and the following relations subsist between the functions of ϕ and ψ:

$$\cosh \psi = \sin \phi = \operatorname{sn} u,$$
$$i \sinh \psi = \cos \phi = \operatorname{cn} u,$$
$$\sqrt{1 - k^2 \cosh^2 \psi} = \sqrt{1 - k^2 \sin^2 \phi} = \operatorname{dn} u.$$

Addition Formulæ.

I append the addition formulæ for the hyperbo-elliptic functions and a few others immediately deducible from them. These may be obtained from the corresponding formulæ of cyclo-elliptic functions by changing the argument u into iu, or they may be deduced independently by integrating the equation

$$dx / \sqrt{(1 + x^2)(1 + k^2 x^2)} = dy / \sqrt{(1 + y^2)(1 + k^2 y^2)}.$$

The addition formulæ are

$$\mathrm{hs}\,(u \pm v) = \frac{\mathrm{hs}\,u . \mathrm{hc}\,v . \mathrm{hd}\,v \pm \mathrm{hc}\,u . \mathrm{hs}\,v . \mathrm{hd}\,u}{1 - k^2\,\mathrm{hs}^2\,u\,\mathrm{hs}^2\,v},$$

$$\mathrm{hc}\,(u \pm v) = \frac{\mathrm{hc}\,u . \mathrm{hc}\,v \pm \mathrm{hs}\,u . \mathrm{hs}\,v . \mathrm{hd}\,u . \mathrm{hd}\,v}{1 - k^2\,\mathrm{hs}^2\,u\,\mathrm{hs}^2\,v},$$

$$\mathrm{hd}\,(u \pm v) = \frac{\mathrm{hd}\,u . \mathrm{hd}\,v \pm k^2\,\mathrm{hs}\,u . \mathrm{hs}\,v . \mathrm{hc}\,u . \mathrm{hc}\,v}{1 - k^2\,\mathrm{hs}^2\,u\,\mathrm{hs}^2\,v}.$$

From the last two of these is obtained also

$$\mathrm{hc}\,(u \pm v) = \mathrm{hc}\,u . \mathrm{hc}\,v \pm \mathrm{hs}\,u . \mathrm{hs}\,v . \mathrm{hd}\,(u \pm v).$$

The following are immediate consequences of the foregoing:

$$\mathrm{hs}\,(u + v) + \mathrm{hs}\,(u - v) = \frac{2\,\mathrm{hs}\,u . \mathrm{hc}\,v . \mathrm{hd} . v}{1 - k^2\,\mathrm{hs}^2\,u\,\mathrm{hs}^2\,v},$$

$$\mathrm{hs}\,(u + v) - \mathrm{hs}\,(u - v) = \frac{2\,\mathrm{hc}\,u . \mathrm{hs}\,v . \mathrm{hd}\,u}{1 - k^2\,\mathrm{hs}^2\,u\,\mathrm{hs}^2\,v},$$

$$\mathrm{hs}\,(u + v) \cdot \mathrm{hs}\,(u - v) = \frac{\mathrm{hs}^2\,u - \mathrm{hs}^2\,v}{1 - k^2\,\mathrm{hs}^2\,u\,\mathrm{hs}^2\,v};$$

$$\mathrm{hs}\,2\,u = \frac{2\,\mathrm{hs}\,u . \mathrm{hc}\,u . \mathrm{hd}\,u}{1 - k^2\,\mathrm{hs}^4\,u},$$

$$\mathrm{hc}\,2\,u = \frac{\mathrm{hc}^2\,u + \mathrm{hs}^2\,u . \mathrm{hd}^2\,u}{1 - k^2\,\mathrm{hs}^4\,u},$$

$$\mathrm{hd}\,2\,u = \frac{\mathrm{hd}^2\,u + k^2\,\mathrm{hs}^2\,u . \mathrm{hc}^2\,u}{1 - k^2\,\mathrm{hs}^4\,u};$$

$$\mathrm{hc}\,2\,u - 1 = \frac{2\,\mathrm{hs}^2\,u . \mathrm{hd}^2\,u}{1 - k^2\,\mathrm{hs}^4\,u},$$

$$\mathrm{hc}\,2\,u + 1 = \frac{2\,\mathrm{hc}^2\,u}{1 - k^2\,\mathrm{hs}^4\,u},$$

$$\mathrm{hd}\,2\,u - 1 = \frac{2\,k^2\,\mathrm{hs}^2\,u . \mathrm{hc}^2\,u}{1 - k^2\,\mathrm{hs}^4\,u},$$

$$\mathrm{hd}\,2\,u + 1 = \frac{2\,\mathrm{hd}^2\,u}{1 - k^2\,\mathrm{hs}^4\,u}.$$

II.

A Classification of Elliptic Differentials of the First Kind.

I sketch, in outline, the classification of elliptic differentials of the first kind into cyclo-elliptic and hyperbo-elliptic groups. Cayley's beautiful transformation of the general differential expression $dv / \sqrt{a + 4bv + 6cv^2 + 4dv^3 + ev^4}$ leads directly to such a classification. I write down Cayley's results without the proofs, referring the reader to the original paper in the *Cambridge and Dublin Mathematical Journal*, vol. I, (1846), pp. 70–73, reprinted in the *Collected Mathematical Papers*, vol. I, pp. 224–227. See also Cayley's *Elliptic Functions*, pp. 317–320.

The investigation shows that if

$$V \equiv a + 4bv + 6cv^2 + 4dv^3 + ev^4$$

be transformed into

$$V' \equiv a'(1 + pv'^2)(1 + qv'^2)$$

by the substitution

$$v = \frac{\lambda + \mu v'}{\lambda_1 + \mu_1 v'}$$

then

$$\frac{dv}{\sqrt{V}} = \left\{ \frac{p^2 + q^2 + 14pq}{12 I} \right\}^{\frac{1}{4}} \frac{\sqrt{a'}\, dv'}{\sqrt{V'}}$$

where

$$I \equiv ae - 4bd + 3c^2,$$

and that if

$$J \equiv ace + 2bcd - ad^2 - eb^2 - c^3,$$

the equation connecting p and q is

$$108\, pq\, (p - q)^4\, I^3 = (p^2 + q^2 + 14pq)^3\, \Delta,$$

where $\Delta \equiv I^3 - 27 J^2$: and finally, that this equation of the sixth degree in q/p or p/q yields, when the discriminant of V is positive, four positive real and two imaginary roots, but when the discriminant is negative, two roots real and negative and four roots imaginary.

Attending to real values only of this ratio, it follows that p and q have the same or different signs according as the discriminant Δ is positive or negative ; or this may be seen directly from the equation in p and q, which, since

$$(\lambda \mu_1 - \lambda_1 \mu)^4\ I = I' \equiv \frac{a'^2}{12} (p^2 + q^2 + 14pq),$$

may be written in the form

$$108\, p\, q\, (p - q)^4\, a'^6 = (\lambda\, \mu_1 - \lambda_1\, \mu)^{12}\, \Delta,$$

whence it appears that the product $p\,q$ must have the same sign as Δ. Hence, we may make the following classification, wherein p and q are now supposed to be positive in all cases, and

$$\begin{aligned} H &\equiv a\,c - b^2, \\ I &\equiv a\,e - 4\,b\,d + 3\,c^2, \\ J &\equiv a\,c\,e + 2\,b\,c\,d - a\,d^2 - e\,b^2 - c^3, \\ \Delta &\equiv I^3 - 27\,J^2. \end{aligned}$$

A. If the discriminant of V be positive, that is, if V be composed of either four real, or four imaginary factors, the coefficients of v'^2 are either both positive, or both negative.

(*i*). If $\Delta > 0$ and both the conditions

$$\mathrm{H} < 0, \quad a^2\, I - 12\, H^2 < 0\,^*$$

be satisfied, all four factors are real, the coefficients of v'^2 are both negative, and

$$\frac{dv}{\sqrt{V}} = \left\{\frac{p^2 + q^2 + 14\,p\,q}{12\,I}\right\}^{\frac{1}{4}} \frac{d\,v'}{\sqrt{(1 - p\,v'^2)\,(1 - q\,v'^2)}}.$$

(*ii*). But if $\Delta > 0$ and either

$$\mathrm{H} > 0, \quad \text{or} \quad a^2\, I - 12\, H^2 > 0,^*$$

all the factors are imaginary, the coefficients of v'^2 are both positive, and

$$\frac{dv}{\sqrt{V}} = \left\{\frac{p^2 + q^2 + 14\,p\,q}{12\,I}\right\}^{\frac{1}{4}} \frac{d\,v'}{\sqrt{(1 + p\,v'^2)\,(1 + q\,v'^2)}}.$$

B. If the discriminant of V be negative, that is, if V be composed of two real and two imaginary factors, then one of the coefficients of v'^2 is positive and the other negative; hence,

if $\Delta < 0$

$$\therefore \quad \frac{dv}{\sqrt{V}} = \left\{\frac{p^2 + q^2 - 14\,p\,q}{12\,I}\right\}^{\frac{1}{4}} \frac{d\,v'}{\sqrt{(1 \pm p\,v'^2)\,(1 \mp q\,v'^2)}}.$$

Each of these three forms, as is well known, is reducible to either of the others by a quadric transformation. Thus the third, by means of the substitution

$$v'^2 = \frac{w^2}{1 \mp p\,w^2}$$

* Burnside and Panton's *Theory of Equations*, p. 143.

becomes

$$\frac{dv}{\sqrt{V}} = \left\{\frac{p^2 + q^2 - 14\,pq}{12\,I}\right\}^{\frac{1}{4}} \frac{dw}{\sqrt{1 \mp p\,w^2 \,.\, 1 \mp (p+q)\,w^2}}$$

and, by a proper choice of signs, the same form of substitution will transform the first or second into one of the others.

The final reductions are accomplished by familiar transformations. Making q/p, or $p/q = k^2$, according as p is greater or less than q, and letting $p\,v'^2$, or $q\,v'^2 = z^2$, in accordance with the same conditions respectively, the three differential expressions become

$$(i) \quad \frac{dv}{\sqrt{V}} = \left\{\frac{k^2 + 14\,k + 1}{12\,I}\right\}^{\frac{1}{4}} \frac{dz}{\sqrt{(1 - z^2)\,(1 - k^2 z^2)}},$$

$$(ii) \quad \frac{dv}{\sqrt{V}} = \left\{\frac{k^2 + 14\,k + 1}{12\,I}\right\}^{\frac{1}{4}} \frac{dz}{\sqrt{(1 + z^2)\,(1 + k^2 z^2)}},$$

$$(iii) \quad \frac{dv}{\sqrt{V}} = \left\{\frac{k^2 - 14\,k + 1}{12\,I}\right\}^{\frac{1}{4}} \frac{dz}{\sqrt{(1 \pm z^2)\,(1 \mp k^2 z^2)}}.$$

If we suppose the given differential to be reduced to either the first or second form, the final substitutions to be made are as follows:

(*i*). *In the first form:* when $z^2 < 1$, the proper substitution is $z = \sin\phi$, and we have the ordinary case

$$\frac{dz}{\sqrt{(1 - z^2)\,(1 - k^2 z^2)}} = \frac{d\phi}{\sqrt{1 - k^2 \sin^2\phi}}.$$

When $z^2 > \frac{1}{k^2}$, ϕ is complex and may be taken $= \frac{\pi}{2} - i\,\psi$; the substitution is $z = \sin\phi = \cosh\psi$, and the differential takes the form

$$\frac{dz}{\sqrt{(z^2 - 1)\,(k^2 z^2 - 1)}} = \frac{d\psi}{\sqrt{k^2 \cosh^2\psi - 1}}.$$

When z^2 lies between 1 and $\frac{1}{k^2}$ the denominator, if it appear in the form $\sqrt{(1 - z^2)\,(1 - k^2 z^2)}$, is imaginary, but we may consider the differential expression $dz/\sqrt{(z^2 - 1)\,(1 - k^2 z^2)}$, and in this case make the substitution $z = \cosh\psi$, by which we obtain

$$\frac{dz}{\sqrt{(z^2 - 1)\,(1 - k^2 z^4)}} = \frac{d\psi}{\sqrt{1 - k^2 \cosh^2\psi}}.$$

(*ii*). *In the second form* the substitution obviously is, for all values of z, $z = \sinh\chi$, and the result is

$$\frac{dz}{\sqrt{(z^2 + 1)\,(k^2 z^2 + 1)}} = \frac{d\chi}{\sqrt{k \sinh^2\chi + 1}}.$$

BERKELEY, September, 1889.

THE SYSTEM OF *ZETA CANCRI.*

By Miss Agnes M. Clerke.

No feature of recent astronomical progress is more curious than the variety of ways in which the multiplicity of stellar combinations has been brought to light. By the analyzing power of great refractors, especially as used by Mr. Burnham, so many stars already divided have been still further broken up; so many apparently binary unions have been resolved into associations of partial systems, as to suggest that the process ceases only through the merging effects of distance from ourselves on the one hand, and of the mutual proximity of the conjoined suns on the other. Spectroscopic revelations —"epoch-making" in character—of exceedingly close bright satellites to bright stars, circulating with great rapidity in periods of a few days, confirm this suspicion. Without undervaluing the prospects of future optical improvement, it may be asserted that few or none of these can ever be rendered accessible to direct scrutiny. At their greatest elongations, the gap of space between them and their primaries makes, from our point of view, too thin a line for possible discernment.

But the telescope may be baffled by lack of light, as well as by lack of room for observation. For aught it can tell, non-luminous "stars" may, according to the conjecture of Laplace, strew the sidereal tracts as plentifully as luminous ones. The modern armory, however, is stocked with multiform weapons of research. Partial eclipses of bright by opaque masses, alleged by Goodricke above a century ago, in explanation of the variability of *Algol*, have been "spectrographically" demonstrated to occur; and the periodical changes of radial velocity detected by Professor Vogel, in April, 1890, in α *Virginis*, and suspected in *Rigel*, show that these stars also belong virtually to the *Algol* class, although our situation is too far removed from their orbital planes to permit the visibility of occultations.

The gravitational influence of unseen masses may also become sensible through disturbance of tangential movement, whether of the translatory, or of the circulatory kind, but under conditions opposite to those favoring "line-of-sight" determinations. That is to say, the orbit of the disturbing body must be both spacious and highly inclined to the visual ray. Thus, the sinuosities of the track pursued across the sphere by *Procyon* would be imperceptible if greatly

foreshortened; and the circumstance that the revolutions of ζ *Cancri* are executed (as it would seem) in a plane differing little from the plane of projection, has alone rendered possible the discovery that a system visually triple is physically quadruple.

The more distant companion at 5″.5 was first noted by TOBIAS MAYER, in 1756, and Father CHRISTIAN MAYER's observation of it at Mannheim, in 1778, already sufficed to show its retrograde motion. HERSCHEL re-divided the larger star in 1781, and, from 1826 onwards, the trio were kept under pretty constant supervision. They proved, for a ternary combination, unusually mobile, the close couple A B mutually revolving in sixty years, their attendant C circling round their optical centre at the average rate of half a degree annually, but, with singular alternations of delay and acceleration, emphasized, too, by the peculiarity of an approach to the centre at each epoch of arrested or inverted angular change, while retreat from it marked the intervals of swifter revolution. Dr. OTTO STRUVE's explanation* of these anomalies by the influence of an obscure mass in the immediate vicinity of the star C, has been fully confirmed by the researches of Professor SEELIGER, in 1880 and 1889.† The looped path pursued by C results, there can be no reasonable doubt, from its circulation round an invisible close companion in a period of about eighteen years, at the same time that it describes a much wider ellipse round the pair A B. Since 1826, it has completed three subordinate revolutions, in an orbit of slight eccentricity, the semi-major axis of which subtends an angle of two-tenths of a second. The dark star D, meanwhile, revolves in the same period round the same centre, and at a distance from it, as Professor SEELIGER has shown, little, if at all, greater than that of C. It cannot, then, be much inferior, and may be greatly superior to it in mass. Yet it does not emit light enough to be discerned, even by Mr. BURNHAM, with the aid of the great Lick refractor. This example alone—and several others might be alleged—proves, with tolerable conclusiveness, that the differences in point of intrinsic brightness between the components of multiple stellar systems does not depend solely upon the swifter cooling of the smaller bodies.

The system of ζ *Cancri*, as we now know it, consists of four masses, closely associated, two and two, together; and it has been demonstrated by Professor SEELIGER that, in combinations of

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* *Comptes Rendus*, t. lxxix, p. 1463.

† *Sitzungsberichte*, Wien, Bd. lxxxiii, Abth. 2, p. 1018; *Denkschriften*, Munich, Bd. xvii, Abth. 1.

this type, KEPLER's law of equal areas holds good for the elliptic movement of the centre of gravity of one pair round the centre of gravity of the other. Thus understood, it is obeyed, within the limits of observational error, by the stars in question. Their individual perturbations, however, constitute a problem in celestial dynamics which, in the actual state of science, can receive only an approximate solution. Their gyrations are, nevertheless, for the present, sufficiently well represented by nearly circular tracks lying respectively in planes deviating little from the plane of projection. Should the larger mutual orbit of the circling pairs prove eventually to be similarly-shaped and situated, then the *annus magnus* of the system is about 720 years; and all its movements, traced out before our eyes with insignificant foreshortening, are directed so as to favor to the utmost telescopic, but to preclude spectroscopic, determinations. But the record of observation must be greatly lengthened before the orbit of C round A B can possibly be computed.

The components of *ζ Cancri* usually show a yellow color; but DEMBOWSKI found them all white, in 1855–57, and noticed, in 1864–65, an obvious change in C to yellowish or olive*. Their magnitudes, photometrically measured at Harvard College as respectively 5.6, 6.3, and 6.0, also perhaps fluctuate slightly, but not so as to disturb the *order* of their brightness. The star A always outshines both B and C; while C, to a trifling extent, surpasses B. The proportion of their masses may, however, differ widely from the proportion of their light. SEELIGER finds that the best agreement with observation is obtained by ascribing to C a mass 2.37 times the combined masses of A and B; but until its period and mean distance have been computed, nothing can really be known on the point.

Should the distance of the system from the earth prove measurable, absolute will be substituted for relative values of mass; but the prospect in this direction is not very encouraging. The "hypothetical parallax" of the couple A B, on MADLER's principle of assuming the two together to possess the same attractive power with our sun, is about five-hundredths of a second, corresponding to a light journey of nearly sixty years; and, since they are likely to be more massive, they are also likely to be more remote. Mass varies in the triplicate ratio of distance; an eight-fold mass implies a double distance, and so on. A small, if not wholly evanescent parallax is also indicated by the secular proper motion of 15″.2, common to the

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* *Astr. Nach.*, No. 1574.

three stars. They appear to be of great intrinsic brilliancy. If of the solar mean density, the stars A B must shine with nine times the solar lustre. This is, indeed, only what we should expect from the quality of their light; but it is a matter for surprise that all the stars yet known to be attended by obscure satellites show Sirian spectra, and stand accordingly themselves at the very summit of luminous intensity.

NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

SKETCH OF THE LIFE OF PROFESSOR ELIAS LOOMIS—BORN 1811; DIED 1889—[BY PROFESSOR H. A. NEWTON].

Professor NEWTON, of Yale College, has published, in an octavo pamphlet of forty-four pages (with a lifelike portrait on steel), a sketch of the life of Professor LOOMIS, who was his colleague and friend for many years.* Professor LOOMIS' life nearly covers the period of the rise of American science, and his solid contributions to many branches of thought are set forth in a most fitting and sympathetic light. The subjects of Terrestrial Magnetism, of Astronomy, of Meteorology, engaged his serious labors for a period of more than fifty years. A list of 164 separate memoirs from his hand is given. Of one of these, Professor NEWTON—a conscientious judge—says that its method is at the foundation of "the new meteorology," and that this paper must be regarded as "the most important in the history of that science." Many of his other works are of capital importance also. At his death he bequeathed the sum of $300,000 from his private fortune to the Observatory of Yale College as an endowment fund, thus assuring the future of an institution for which he had already done much. Professor LOOMIS was one of the group of men who were the founders of American science, and his high claims to the gratitude and respect of his countrymen are established by his biographer. His name is most generally known through the admirable series of text-books which he printed from time to time, and which brought him a large fortune. His chief interest was always "in abstract science without any regard to its practical applications," and his life is one long record of a steady following of

* This memoir has lately been reprinted in the *Sidereal Messenger* for June, 1890.

his own ideals. Yale College has reason to be proud of its distinguished company of astronomers, of which LOOMIS was so prominent a member. The Lick Observatory, and every observatory in America, owes more to their efforts and influence than is easily expressed. E. S. H.

THE ROTATION OF THE SUN, [BY PROFESSOR N. C. DUNÉR, DIRECTOR OF THE OBSERVATORY OF UPSALA].

From a note in the *Astronomische Nachrichten*, No. 2968, the following very brief summary is made:

During the years 1887-8-9 Professor DUNÉR studied the laws of the rotation of the surface of the sun at different latitudes, by means of a spectroscope and a ROWLAND grating. The method employed was to compare the spectra of the two borders of the sun. One of these borders is moving towards the earth, the other is moving away from it. Hence the spectral lines of the former are shifted towards the violet end of the spectrum, while the lines of the latter are shifted towards the red end.

Measures of the amount of the displacement give a means of calculating the velocity of the motion towards or from the earth, expressed in miles, and this velocity is, of course, a measure of the angular rotation of the surface of the sun at the particular latitude in question. The measures of Professor DUNÉR were extremely precise, and the following results must be very near the truth. I have added the third column, where his results are expressed in a familiar unit:

Heliocentric Latitude.	Angle through which the sun's surface turns in 24 hours.	Period in Days.
$0^\circ.4$	$14^\circ.14$	25.5
15.0	13.66	26.4
30.0	13.06	27.6
45.0	11.99	30.0
60.0	10.62	33.9
74.8	9.34	38.6

Professor DUNÉR says that the values in the second column "confirm what has already been revealed by observations on the

solar spots; to wit, that the times of rotation of the different zones of the solar surface are not the same, and that the equatorial zone makes a revolution in the shortest period, while the duration of a single rotation increases with the latitude. But, while solar spots are only exceptionally present in latitudes greater than ± 35° (and almost never in latitudes greater than 45°), and while 55° is the highest latitude in which any spot has ever been seen, it follows that, up to the present time, nothing is known of the rotation of the polar regions of the sun. These observations, then, extend our knowledge of the circumstances of the rotation of the sun's surface up to latitude 75°, quite in the neighborhood of the poles."

A comparison between the spectroscopic observations of Professor DUNÉR and those depending on solar spots and solar faculæ, shows that the latter give a velocity of rotation somewhat less than the former. This may be due to the fact that the spots, etc., correspond to depths in the solar atmosphere which are different from that of the layer which gives the spectra which he has observed. This peculiar law of the sun's rotation shows conclusively that it is not a rigid body, in which case every one of its layers in every latitude must necessarily rotate in the same time. It is more like a vast whirlpool where the velocities of rotation depend not only on the situation of the rotating masses as to latitude, but also as to depth beneath the exterior surface.

E. S. H.

THE "SQUARE-SHOULDERED" ASPECT OF *SATURN*.

It is known that Sir WILLIAM HERSCHEL (in *Philosophical Transactions*, 1805, page 272 and Plate IX) described a "square-shouldered" aspect to the ball of the planet *Saturn*. The ball appeared to him neither circular nor elliptic, but like "a parallelogram with the four corners rounded off," in latitude 43° or thereabouts. I have lately received, through the kindness of Mr. W. H. PICKERING, a silver print of a negative of *Saturn*, taken at Wilson's Peak February 7, 1890, at $18^h\ 54^m$, G. m. t., enlarged to a scale of 1″ of arc = 1 millimetre, approximately. The dark south polar cap, which has been constantly visible on the planet for some time (certainly ever since the Lick Observatory has been in operation), shows far more plainly in this print than it does to the eye, even, and gives to the southern hemisphere of the planet precisely the "square-shouldered" aspect described by HERSCHEL for both hemispheres. If the northern hemisphere had been marked as the southern

one actually was, HERSCHEL's drawing of 1805 would have been reproduced. It therefore appears to me that Mr. PICKERING's interesting photograph is a sufficient explanation of the anomalous figure of *Saturn* described by HERSCHEL. E. S. H.

SCIENTIFIC VISITORS TO THE LICK OBSERVATORY.

Mrs. R. A. PROCTOR has made an extended visit to the Lick Observatory, which was utilized in examining the work of the various departments and in actually studying the principal celestial objects, with special reference to her courses of astronomical lectures, already prepared, and to the preparation of new ones.——We learn that we are also to have the pleasure of seeing Dr. M. WILHELM MEYER, of Berlin, and Mr. COMMON, of London, during the present year. A few such visits will go very far towards breaking up our present sense of physical isolation, which is the only drawback to life at Mt. Hamilton.——Mr. W. W. CAMPBELL, Instructor of Astronomy in the University of Michigan, proposes to spend his summer here in practice with some of the instruments. E. S. H.

THE CONSTANTS OF THE REPSOLD MERIDIAN-CIRCLE OF THE LICK OBSERVATORY.

The constants of the meridian-circle of the Lick Observatory were observed daily, with few exceptions, during the time from October, 1888, to May, 1889, under the supervision of Prof. SCHAEBERLE, in charge of the instrument. The total number of determinations amounts to about one thousand. The observations, together with the temperature, were represented by curves, and the entire material was discussed. The following laws represent the variations of the constants with the temperature during the period of observation:

1. The *variations in the instrument* are greatest when the shutters are open during the night.

2. The *collimation* is quite constant and almost independent of changes of temperature, but shows a systematic decrease of 0ˢ.002 a month from December, 1888, to May, 1889.

3. The *level-constant* varies inversely with the temperature, a change of one degree in the latter producing a change of 0ˢ.025 in the former. The level-constant increased systematically 0ˢ.005 a month for the time from October, 1888, to February, 1889.

4. The reading of the *azimuth-mark* (mire) varies directly with the temperature for micrometer-head west.

5. The reading of the *setting of the south on the north collimator*

varies directly with the temperature, a change of one degree in the latter producing a change of $0^s.018$ in the former. Besides, the setting increased systematically about $0^s.010$ a month.

6. The reading of the ***nadir-point*** varies $\left\{\begin{smallmatrix}\text{inversely}\\ \text{directly}\end{smallmatrix}\right\}$ as the temperature for circle $\left\{\begin{smallmatrix}\text{east}\\ \text{west}\end{smallmatrix}\right\}$, a temperature change of one degree producing a change of $0''.15$ in the reading of the nadir-point.

7. The ***flexure*** is quite constant, its mean value being $+ 0''.16 \pm 0''.026$.

8. Cold and moist weather causes a separation of the piers; dry and hot weather, the reverse.

ARMIN O. LEUSCHNER.

LICK OBSERVATORY, March, 1890.

THE BOYDEN PREMIUM.

Mr. U. A. BOYDEN, of Boston, has deposited with the Franklin Institute of Philadelphia the sum of $1000, which will be awarded as a prize "to any resident of North America who shall determine by experiment whether all rays of light, and other physical rays, are or are not transmitted with the same velocity." The competition is to close on January 1, 1891. Particulars may be found in the advertising pages of the *Journal of the Franklin Institute.*

COMPARISON OF THE SENSITIVENESS OF THE EYE AND OF THE PHOTOGRAPHIC PLATE.

[BY A. C. RANYARD, F. R. A. S.]

"Sensitive as are the salts of silver in the dry-plates at present in use, they do not correspond in sensitiveness with the living matter of the retina, on which images of comparatively faint objects are continually being impressed and obliterated. When we look at a faint object, and the pupil is fully expanded, the eye may be compared to a camera with a focal length of about four times its aperture. With such a camera it would be useless to attempt to photograph objects illuminated by candle-light in a fraction of a second. Yet the eye will perceive a succession of such faintly illuminated objects in a small fraction of a second, as any one may satisfy himself by watching any quickly-moving objects illuminated by the light of a candle, or even by a much fainter light."—From *Knowledge*, June 2, 1890 (page 157).

CORRIGENDA.

Vol. II, page 99, lines 20–22: The order of the numbers *should be* 194, 248, 175, 143 *instead of* 143, 248, 194, 175. A. O. L.

DIFFERENCES OF DECLINATION FOR VALUE OF THIRTY-SIX-INCH MICROMETER SCREW.

[MEASURED BY S. W. BURNHAM.]

1889.	STARS.	Assumed dif. Decl.	Extreme Readings of Micrometer head.	One rev.
		"		"
Aug. 12	υ^1 and υ^2 *Cassiopeæ*	755.5	30 to 62.2	9.912
"	do.	. . .	30 to 78.1	9.921
Aug. 14	do.	. . .	30 to 78.1	9.921
"	o and 2 *Andromedæ*	1553.69	30 to 76.4	9.902
Aug. 20	*Merope* and *Alcyone*	573.61	30 to 70.3	9.890
"	19 and 20 *Tauri*	353.33	30 to 65.7	9.897
Sept. 9	do.	. . .	104.3 to 30	9.901
"	*Merope* and *Alcyone*	573.61	30 to 70.3	9.910
"	κ^1 and κ^2 *Tauri*	337.93	64.1 to 106.0 double dist.	9.918
"	θ^1 and θ^2 *Tauri*	327.51	106.9 to 30	9.891
Sept. 11	do.	. . .	106.9 to 30	9.893
"	κ^1 and κ^2 *Tauri*	337.93	105.9 to 30	9.904
"	19 and 20 *Tauri*	353.33	104.3 to 30	9.903
"	*Merope* and *Alcyone*	573.61	47.6 to 70.3	9.907
Sept. 16	19 and 20 *Tauri*	353.33	104.4 to 30	9.904
"	κ^1 and κ^2 *Tauri*	337.93	106.0 to 30	9.924
Aug. 20	S D. $-4^\circ.4926$ and $-5^\circ.5075$	729.17	17.2 to 42.8 104.3 to 65.7	9.921
				Mean = 9.907

RECORDS OF CALIFORNIA EARTHQUAKES.

A list of all recorded earthquakes in California and adjacent States from 1769 to 1888 has been printed as a separate work.* A catalogue of shocks for the year 1888 is given in the *American Journal of Science.*† A discussion of the special data for San Francisco is also printed in the same journal.‡

* *List of Recorded Earthquakes in California, Lower California, Oregon and Washington Territory.* (Sacramento: State Printing Office. 1887.)

† *Earthquakes in California* (1888). (*American Journal of Science*, Vol. XXXVII, May, 1889.)

‡ *Note on Earthquake Intensity in San Francisco.* (*American Journal of Science*, Vol. XXXV, June, 1888.)

The records for 1889 (compiled by Mr. KEELER) and for future years will be published by the United States Geological Survey in its *Bulletins*, under the editorship of G. K. GILBERT, United States Geologist, according to an arrangement recently made. Members of the Society can aid in making these lists complete, if they will transmit to the Lick Observatory any printed or MS. accounts of shocks which occur in California. All such contributions will be gratefully received and promptly acknowledged. E. S. H.

BANDS ON THE PLANET *URANUS*.

On April 13, 1890, two observers were satisfied that the planet *Uranus* had two faint bands on its surface. Their position angle was estimated at 90° ± by E. S. H., 105° ± by J. M. S.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD AT THE LICK OBSERVATORY, JULY 12, 1890.

A quorum was present. The minutes of the last meeting were read and approved.

The following memorandum was presented:

ACTION OF THE MERCANTILE LIBRARY ASSOCIATION, RELATING TO THE CARE OF THE BOOKS BELONGING TO THE ASTRONOMICAL SOCIETY OF THE PACIFIC.

On Tuesday, April 1, 1890, at a meeting of the Mercantile Library Association, of San Francisco, on motion of Mr. WATKINS, it was voted—"that the Astronomical Society of the Pacific be permitted to place the books belonging to them in the rooms of the Mercantile Library Association, and that the members of the Association shall have the privilege of using said books in the Library rooms; the books to be subject to the same regulations as the books of the Library Association, and the Library not to assume any responsibility therefor."

The President and Secretary of the A. S. P. (duly authorized thereto, May 31, 1890), in a letter dated June 16, 1890, have on the part of the Society, accepted this courteous offer, and have expressed to the Directors of the Mercantile Library Association its cordial thanks.

The following members* were duly elected:

THEODORE ADAMS,	833 N. Broad Street, Philadelphia, Pa.
Rev. FRANK H. BIGELOW,	Nautical Almanac Office, Washington, D. C.
W. W. CAMPBELL,	Observatory, Ann Arbor, Michigan.
F. J. CASTELHUN,	502 Montgomery Street, S. F., Cal.
E. A. DENICKE,	403 Market Street, S. F., Cal.
THOMAS GWYN ELGER, F. R. A. S.,	Beaumont House, Shakespeare Road, Bedford, England.
H. GRATTAN GUINNESS, D. D., F.R.G.S.	Bow, London, England.
G. E. HALE,	4545 Drexel Boulevard, Chicago, Ills.
Hon. A. KING,	Julian Street, San José, Cal.
JAMES JENNINGS MCCOMB,	175 W. 58th Street, New York City.
W. H. S. MONCK, F. R. A. S.,	16 Earlsfort Terrace, Dublin, Ireland.
Hon. B. D. MURPHY,*	San José, Cal.
THE NEWBERRY LIBRARY,	Chicago, Ills.
HENRY PHIPPS, JR.,	Carnagie, Phipps & Co., Pittsburgh, Penn.
Mrs. R. A. PROCTOR,	St. Joseph, Missouri.
A. COWPER RANYARD,* F. R. A. S.,	11 Stone Buildings, Lincoln's Inn, London, England.
J. W. STATELER,	957 Market Street, S. F., Cal.
Hon. J. W. TOWNER,	Santa Ana, Orange Co., Cal.
FRED'K W. ZEILE,*	Pacific-Union Club, S. F., Cal.

Professor W. STEADMAN ALDIS, University College, Auckland, New Zealand, was duly elected a life member.

It was on motion duly seconded,

Resolved, That a new diploma be issued to Dr. J. C. HAWVER, to replace his original diploma, destroyed by an accidental fire.

Resolved, That the President and Secretary be authorized to make application to the California Academy of Sciences, for space in the new Academy

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* An asterisk (*) is affixed to the names of Life Members duly elected.

building, and that Mr. PIERSON, Vice-President, be given full power as to the disposition of the space in question.

Resolved, That the resolution of May 31, 1890, fixing the bond of the Treasurer at $5000 be rescinded, and

Resolved, That the amount of the said bond to be given for the present year be fixed at $500.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT THE LICK OBSERVATORY, JULY 12, 1890.

The minutes of the last meeting were read and approved.

The Secretary read a list of presents received since the last meeting, and the thanks of the Society were voted to the givers.

The list of new members elected was read by the Secretary.

A silver-print of a crayon drawing made from negatives of the Solar Eclipse of January 1, 1889, by Rev. C. M. CHARROPPIN, was exhibited to the meeting. Mr. HOLDEN also exhibited the first enlargements of the planet *Jupiter*, made by the great telescope on July 8, 1890. The planet is photographed direct, so that the major axis is nine-tenths of an inch, and the results are very promising. It seems likely that the history of the larger changes on the planet's surface can be satisfactorily followed by means of such pictures, leaving the study of the minuter features to visual observation.

The following papers were presented:

a. Dr. W. MEYER: "The Urania Gesellschaft of Berlin."

b. Prof. E. S. HOLDEN: "Astronomical Photography at the Lick Observatory."

c. J. E. KEELER: "The Chromatic Aberration of the Thirty-six-inch Equatorial."

d. Rev. GEO. M. SEARLE: "Are the Planets Habitable?"

e. Prof. I. STRINGHAM: "On Hyperbo-Elliptic Functions."

f. Miss AGNES M. CLERKE: "On the Multiple System of *Zeta Cancri*."

Only papers *a* and *c* were read. All are printed in the present number of the *Publications*.

Adjourned.

OFFICERS OF THE SOCIETY.

EDWARD S. HOLDEN (Lick Observatory),	*President*
WM. M. PIERSON (76 Nevada Block, S. F.),	*Vice-Presidents*
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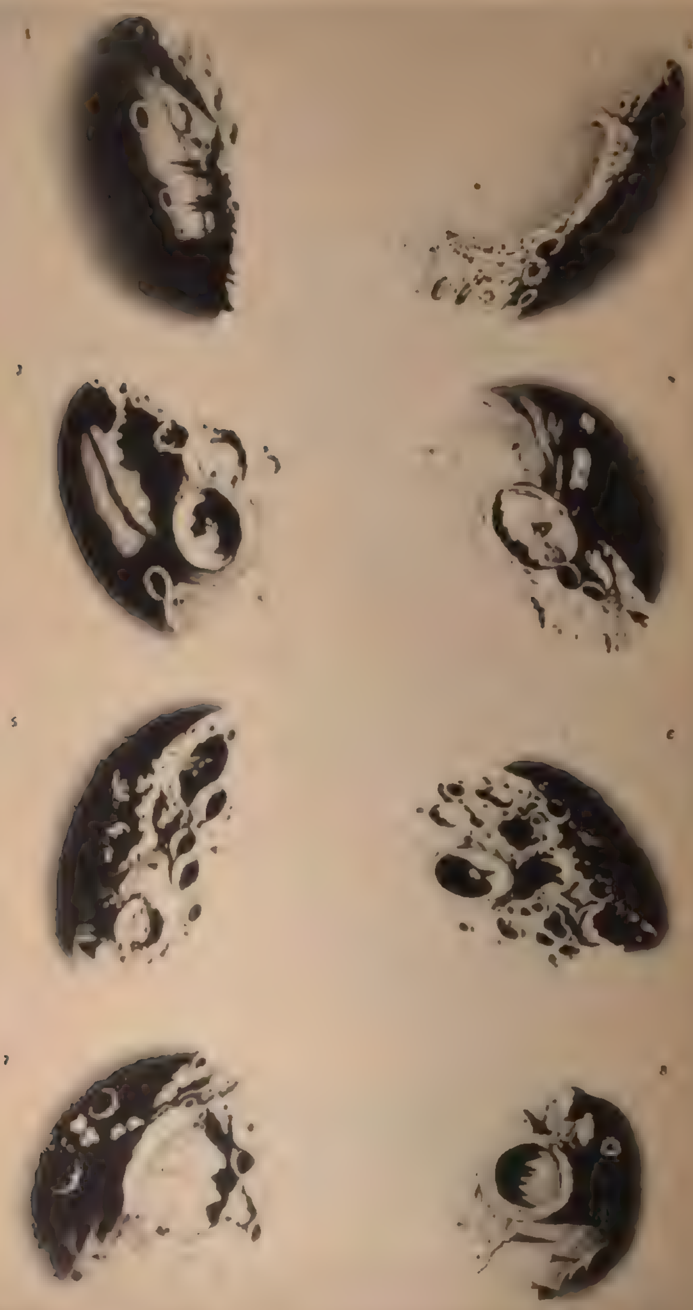

Drawings of the Moon, by Professor Weinek.

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DRAWINGS OF THE MOON.*

BY PROF. DR. L. WEINEK; DIRECTOR OF THE IMPERIAL OBSERVATORY AT PRAGUE.

When, by the invention of the telescope, the eye of the astronomer was sharpened to an undreamed-of extent, and the most wonderful mountain sceneries, with constantly changing shadows, were discovered on the moon, our nearest celestial neighbor, several observers immediately undertook to make drawings of what they saw, partly to advance the knowledge which we had of our satellite and its singular surface formations, and partly to lay a foundation, for future generations, for the solution of the question whether any changes take place on the moon which can be detected by the inhabitants of the earth. It is obvious that the production of such maps, with their rich detail, requires equal perseverance and ability, and we cannot fail to admire the courage of the gifted men who devoted themselves to the solution of this extensive and difficult task.

Among the most important selenographers of the seventeenth century we must mention HEVELIUS, proprietor of a brewery in Danzig and mayor of the city, who gained great renown by his work "*Selenographia sive Lunæ Descriptio*," which was published in 1647 in folio. His work is founded on observations of the moon made during a period of five years, through telescopes of six and eight feet focus (instruments of his own construction), with a magnifying power of thirty to forty diameters, and contains, in addition to forty pictures of the different phases of the moon, comprising the period of a whole lunation, three maps of the full moon, of which the largest has a diameter of 28.5 centimeters (11.22 inches). All of these plates were not only drawn, but even engraved on copper, by HEVELIUS personally.

The principal plate of the moon shows the crater formations,

* English translation by Mr. F. R. ZIEL.

throwing short shadows towards the west, the shading being by lines, either wide or near together, so as to give the proper character to the dark or light portions of the disc. Although this map was based on only approximate positions, it remained the best one in existence for over one hundred years.

In the middle of the eighteenth century TOBIAS MAYER, of Goettingen, Professor of Agriculture and Mathematics, created a new and fundamental epoch in the study of the surface of the moon, by exact measurements of twenty-four lunar objects, and by adding to these some sixty-three points whose positions were very approximately established. After reducing these measurements to *mean* libration, he obtained a chart of the moon, with a diameter of 20.3 centimeters (7.99 inches). This chart was not published till after his death (1762), in the year 1775. It was superior to the one made by HEVELIUS in correctness and finish, and ranked as the best map of the moon until the year 1824.

By the aid of MAYER'S rich collection of drawings, KLINKERFUES published—in the year 1881—a map of the full moon, having a diameter of 35 centimeters (13.78 inches), with numerous pictures of special regions, under the title "TOBIAS MAYER'S *groessere Mondkarte nebst Detailzeichnungen*," in which all objects are represented as throwing shadows towards the east. The photo-lithographic reproduction shows the skill of the maker, although he was unable to devote himself to very minute details, having undertaken too extensive tasks for the single nights of observation.

The most important selenographers of this century, as LOHRMANN, MAEDLER and SCHMIDT, follow the principle introduced into astronomy by LOHRMANN himself, and which is taken from the manner of presenting terrestrial elevations brought into prominence by LEHMANN († 1811), a major in the Saxon army, and now universally used.

"According to this theory—to make use of LOHRMANN'S own words—we suppose ourselves to be stationed vertically above each point of the section under observation, and to see all the mountain sides in their proper horizontal distances from each other, this being the only manner in which they can be accurately represented. The different ridges of the mountains will then have greater or lesser inclinations to the accepted vertical lines of sight, according to their relative steepness.

"Now, if we assume the mountains to be illuminated vertically, then the *horizontal* planes will reflect the most light, and the slanting

sides will reflect the faintest light. This difference in the illumination has, therefore, been recognized to be the natural manner of representing the mountains—in accordance with the truth—by the change from white to black. But as a mountain range can only be distinguished, as regards its position, when we know the direction of the slope as well as its steepness, we employ—in order to be able to meet both requirements in a satisfactory manner—black lines for the slopes, and draw the mountains by their aid, so that the lines always stand vertically to the horizontal contour lines with which we imagine the mountain to be covered. These vertical lines indicate by their position the direction, and by their thickness and proximity the steepness, of the slope."

LEHMANN, in making terrestrial maps, represented the horizontal plane as white and the inclined plane of 45° as completely black. In dealing with the moon, it became necessary to extend this scale to 90° on account of the great steepness of the lunar mountains, so that LOHRMANN represented the horizontal plane by white, the slant of 45° by half-dark, and the perpendicular precipice of 90° by black shading.

The charts of these three renowned selenographers are so well known that they require but brief mention. LOHRMANN conducted his observations in Dresden with a telescope of four and a-half inches diameter and a smaller one of three inches diameter. He made his first trials in measuring and drawing during the winter of 1821 and 1822. His continued observations for the production of a general chart of the moon having a diameter of three Paris feet (97.45 centimetres) in twenty-five sections, were commenced in the autumn of 1822.

Only four of these sections were published by LOHRMANN himself, on copper plates, in the year 1824, entitled "*Topographie der sichtbaren Mondoberflaeche, Erste Abtheilung*"; whereas the publication of the whole twenty-five sections—completed in 1878—took place long after his death (1840), under the editorship of SCHMIDT. LOHRMANN'S only other publication was a small map of the moon (diameter, 38.5 centimetres), in 1838, which was a lithographic print, showing, however, very rich detail, beautifully executed.

As already stated, the diameter of LOHRMANN'S large chart is three Paris feet—*i. e.*, one-half toise. Now, as the true diameter of the moon is equal to 468.4 geographical miles, or 1,783,200 toises, the former is 3,566,400 times larger than that of the chart, which

makes the scale of the latter 1 : 3,566,400. As a consequence, LOHRMANN's chart is on the scale:

$$
\begin{aligned}
1^{mm} &= 3566.4 \text{ metres.} \\
&= 0.48062 \text{ geogr. miles.} \\
&= 1''.91374.
\end{aligned}
$$

Although the drawing and engraving of this chart is most beautiful, it does not represent the principal characteristics of the crater formations quite correctly, inasmuch as it shows too broad summit rims; moreover, the gradations of light and dark shades of the surface of the moon are not correctly represented.

MAEDLER made his observations in Berlin, with BEER, the banker, at the private observatory of the latter, with a telescope of only three and a-half inches aperture. Their observations of the moon commenced in 1830, and were completed in 1836. Their chart was published in four sections, entitled "*Mappa Selenographica*," in 1834–1836, by means of a lithographic reproduction, and had the same diameter as that of LOHRMANN.

Their next publication, issued in 1837, was the excellent and instructive work, entitled "*Der Mond, nach seinen kosmischen und individuellen Verhaeltnissen, oder allgemeine vergleichende Selenographie*," and in 1838 a small chart of the moon, with a diameter of 32.5 centimetres (12.80 inches), was published, likewise by the aid of lithography. MAEDLER's large moon chart reproduces the individuality of the mountain formations beautifully, and is unequaled in detail and exactness, so far as the power of the instrument used by him permitted.

SCHMIDT is, with MAEDLER, one of the most thorough observers of the moon. He commenced his drawings of the moon in 1840, in his native city, Eutin, and continued them, during his whole life, at different places. In the year 1858 he commenced working in Athens, as director of the observatory of that city, with a telescope of six inches aperture; and this period may be regarded as the most successful time of his work in connection with the moon. SCHMIDT's general chart, completed in 1874, and reproduced from his original drawings by the heliotype process, has a diameter as large again (namely, 1.949 metres), as that of LOHRMANN, and is based on the position determinations of the latter. It shows an astonishing amount of detail, which requires no explanation, and the drawing of which is based on observations made during a period of no less than thirty-two years.

On this chart, the scale of which is 1 : 1,783,200, and which shows 32,856 separate ring mountain formations and 348 "rills," the relations are:

$$
\begin{aligned}
1^{\,\mathrm{mm}} &= 1783.2 \text{ metres.} \\
&= 0.24031 \text{ geogr. miles.} \\
&= 0''.97687.
\end{aligned}
$$

Although this map does not give the correct impression of the differences in elevation as they actually appear on the moon, inasmuch as small ridges and veins are drawn much too prominently (so as to make the original map suited for the photographic reproduction of his drawing, which Schmidt contemplated making), and is inferior to the charts of Maedler and Lohrmann as regards fineness, it is, nevertheless, a most trustworthy production, owing to its unusually rich detail, and is an example of untiring industry. This chart may be considered as presenting the limit of what a single observer can achieve during a short human life in this branch of astronomy, which unquestionably belongs to the most arduous in the science, and requires special adaptations on the part of the observer.

We may further mention the chart of Neison, which is partly based on that of Beer and Maedler, and partly on numerous measurements made by himself, and which is very generally used, owing to its convenient size. This chart consists of twenty-two sections in octavo, which, connected, give a diameter of the moon of 61.0 centimetres (twenty-four inches). The relatively small scale of this map does not permit the character of the slopes of the mountains to be sufficiently shown, nor is any attention paid to the general shading of the moon; so that it is more of a map of reference than a true picture of the lunar surface. The accompanying textbook, however, entitled "*The Moon, and the Condition and Configuration of its Surface, 1876*," which states all that is known in regard to the surface of the moon in a very concise and clear manner, is of great importance, owing to the many new points of view which it presents. While the remarkable works which we have mentioned addressed themselves to the difficult ideal of representing the entire surface of the moon which is visible to us, other observers have confined themselves to special portions of the moon's disc, in order to be able to study and draw the details more carefully. In this connection, we must mention the exhaustive work of Schroeter, the industrious observer of Lilienthal, near Bremen, which appeared in 1791 and 1802, in two volumes, entitled "*Selenotopographische Frag-*

mente zur genauen Kenntniss der Mondflaeche," and containing sixty-eight plates of special regions of the moon, observed with reflecting telescopes of four, seven, thirteen and twenty-seven feet in length, and with powers of one hundred and fifty to three hundred diameters. SCHROETER's object was, as he expresses himself, to represent a series of different portions of the moon with such truth and completeness, that in times to come a comparison of these drawings would show any changes which might have taken place on the moon. The plates, which indicate the shadows cast by the mountains and craters, show at once that SCHROETER was not an expert draughtsman, and that he tried to do more than his ability in this direction would permit. A truthful plastic effect is nowhere observable, and all the shadings are most arbitrary; in fact, the characters of all elevations, and especially the walls of the craters, are not truthfully represented; the latter, indeed, look like nothing but ordinary slopes. There is no question, however, but that an experienced selenographer can make even these charts serve a very useful purpose, by paying more attention to what they are intended to represent, than to the manner in which it is accomplished, and by referring to the accompanying text, which is based upon very thorough observations.

GRUITHUISEN's detail-drawings of the moon are much more natural; of these, forty-seven, made during the years of 1821 to 1827, were published by KLEIN in the seventh volume of "*Sirius*," reproduced by the aid of photo-lithography. Although KLEIN said, in 1879, that these drawings were the best and most complete which he had ever seen, and expressed his admiration of their truthfulness and fine execution, I cannot quite agree with him, as I am disposed to lay great stress upon the accuracy of scale in all such plastic drawings of the moon.

In recent years such detail-observations have had much attention, which was a move in the right direction, showing that the advancement of selenography depends, to a great extent, upon the continuation and careful additions to the results obtained by LOHRMANN, MAEDLER and SCHMIDT.

This fully confirms the introductory remarks which MAEDLER makes in his work, namely: Selenography will advance, as geography has advanced for centuries, and still advances, but with the difference that the latter rises from the local to the general, while the former pursues the contrary course.

Two methods have been employed in drawings of the moon—first, by representing the lunar features by means of conventional

signs; and, secondly, by giving truthful, plastic and picturesque representations of the different details.

Although the first method admits of a reproduction of the horizontal extension of the objects, as well as of their vertical elevation above the surface of the moon, it always requires a double interpretation, namely: that from the object to the conventional signs, for the observer, and that from these signs back to the object, for the reader. This must produce confusion and uncertainty, which drawbacks will be increased by the fact that this method is usually employed by draughtsmen of but little skill; and it is, therefore, by no means the best one for the production of a reliable document, to be used in the future. The second method only can be regarded as entirely trustworthy; it does not require interpretation by the reader, but reproduces the impressions of the eye with all the outlines, lights and shades; every one understands it, and every one can satisfy himself of its truthfulness to nature by a direct comparison. Naturally, a representation which is to compete with a photographic reproduction requires the greatest proficiency in drawing, and special practice in this branch; as plastic drawings, taken from the bird's-eye view—*i. e.*, such as will, by close attention to minute detail, show the elevations in the line of sight,—are the most difficult to produce.

I repeat that the greatest proficiency in drawing is necessary, not only on account of the endless variety of what is seen, but also on account of the rapid changes in color and shadows on the moon. Only the most trained eye, together with an unerring hand, will be able to produce the required truthfulness of the drawing. Unfortunately, this requirement is often overlooked, so that there is no lack of quantity, but a great one of quality.

I know some astronomers who draw objects in the heavens without ever having attempted to draw a terrestrial object from nature, and who, therefore, are far from possessing the ability to make correct representations. This is the reason why the illustrated parts of astronomical works generally appear to have been collected indiscriminately or to have been imperfectly reproduced, and as if more attention had been paid to their appearance than to their truthfulness. This is of particular importance in popular works, as the layman is not in a position to make observations personally, but must derive almost all his impressions of heavenly bodies from books.

But even that expertness in drawing which is universally considered as an accomplishment, and which generally amounts to but little, is entirely inadequate when drawings of the moon are in ques-

tion. I should feel like demanding of a competent draughtsman, that he not only should be able to make a truthful picture of a terrestrial landscape, but also that he should have proved his competence in the portraiture of persons, as the latter branch permits of no latitude for arbitrariness, which is not excluded in the drawing of landscapes, and consequently forms the best practice for learning to make an absolutely correct copy. He should also be proficient in drawing miniatures, as it is of importance, in dealing with the moon, to represent as much as possible in a small space. In this connection, we may consider the question, what scale the draughtsman of the moon should adopt. If the picture is to appear natural, it must not make very small or uncertain objects any larger or more distinct than they appear with the enlargement employed or under the momentary conditions of the atmosphere. Anything that, in reality, lies at the boundary of visibility, should only be indicated feebly in the picture. This principle is generally disregarded. Partly to give a free movement to the inexperienced hand, and partly to produce something prominent, some special regions of the moon are pictured too large and quite out of proportion, so that small craters and faint ridges are shown with great distinctness—as if these objects could be observed with the greatest ease; while, on the other hand, large plains of the picture are devoid of detail or show incomplete and incorrect shadings, which by no means coincide with the real formations of the moon's surface.

If we consider the magnifying power employed to be m, the corresponding angle under which the object appears in the objective may be called β. Now, if the angle at which the same object appears to the naked eye be α, we shall have, for objects that are not too much extended, the relation $\beta = m\,\alpha$.

The cone of rays which the eye receives from the eye-piece, with the object as a base, is now conceived by the draughtsman to be cut by the plane of his drawing.

The diameter l of this section gives the proper scale for the size of the drawing. If the distance between the drawing-paper and the eye be d, then $l = d \operatorname{tg} \beta$, and approximately $l = d\,\beta \sin 1''$, which gives $l = d \,.\, m \,.\, \alpha \,.\, \sin 1''$.

As an example, let us consider the mighty ring-mountain *Copernicus*, which has—according to MAEDLER—a diameter of 12.15 geogr. miles. As on the moon, at its mean distance, $1'' = 0.25114$ geogr. miles, it follows for the latter $\alpha = 48''.379$. Now, if we substitute for d the distance of distinct vision, 250 millimeters, and then

a smaller value, $d = 200$ millimeters, and also a variety of enlargements from 100 to 1000, we shall have the following table:

Magnifying Power.	Visual Distance = 250 m. m. Lineal Diameter *l* of *Copernicus*.	Visual Distance = 200 m. m. Lineal Diameter *l* of *Copernicus*.
	m. m.	m. m.
100	5.9	4.7
200	11.7	9.4
300	17.6	14.1
400	23.5	18.8
500	29.3	23.5
600	35.2	28.1
700	41.0	32.8
800	46.9	37.5
900	52.8	42.2
1000	58.6	46.9

Now, if we draw *Copernicus* with a diameter of six centimeters (with a distance of twenty-five centimeters from the paper to the eye), and only employ a magnifying power of twenty-five times, we have really taken the size corresponding to an enlargement of 1000 times, and the picture shows no more detail than if this crater had only been made the size of one centimeter. In the latter case, a good and conscientious draughtsman can execute the picture in a much more complete manner than in the former, so that for this reason, also, the advantage lies with the smaller scale. A selenographer who is proficient, from having drawn portraits and landscapes, will unconsciously choose the scales which we have mentioned, and will only allow himself to exceed them when the condition of the atmosphere is excellent and the detail is exceptionally rich.

As regards objects situated at the limit of visibility, their exact representation must be left to larger instruments, which are able to define *at once* that which the smaller instrument can only discern by laborious observation, and even then only incompletely.

The most pleasing pictures of the moon, as regards picturesqueness and plastic effect, were produced by NASMYTH and CARPENTER, in their work, "*The Moon, Considered as a Planet, a World and a*

Satellite," 1874. It is only to be regretted that their excellent pictures were not taken from nature direct, but consist of photographs of plastic models, which were executed from drawings, based on observations made during thirty years, mostly with a reflector of twenty inches. Even if the originals—which, unfortunately, were never published—had been of the greatest truthfulness, their conversion into relief would—owing to the captivating abundance of detail which is offered by the authors—produce untruths, which again lessen the value of these productions. Nevertheless, these pictures give us a better idea of the character of the scenery of the moon and its wonderful views than those of any other selenographer before that time. Among the best of similar drawings, we have TROUVELOT's fifteen pictures in the "*Annals of the Astronomical Observatory of Harvard College*," Vol. VIII, although they are not devoid of mannerism, and represent the formations somewhat as if they were made of dough.

Among the authors of the remaining numerous sketches of picturesque and plastic scenery of the moon, several have produced work of equal value, but the manner in which the results of their labors is reproduced generally leaves much to be desired.

As the work which had been done in this direction did not completely satisfy me, because it either did not consider half-tones at all, or at best only very carelessly, and therefore was lacking in plasticity and truthfulness, I came to the conclusion, in the year 1884, relying on my long practice in drawing and painting of every description, that I would devote a portion of my spare time, at the observatory at Prague, to plastic drawings of some portions of the moon.

I was actuated principally by the desire to reproduce the magnificent beauty of the landscapes of the moon as truthfully as possible. I further had the desire to lay a foundation for the solution of the question, in the future, regarding changes on the moon, by making truthful and complete drawings of regions close to the boundary of illumination, where the eye meets with great contrasts of light and shade. I chose the terminator, because it is the point at which photography encounters the greatest obstacles.

As the photographic plate, with a given time of exposure, will only be impressed by certain intensities of light, and the light parts will be over-exposed, while the dark ones are under-exposed, it cannot give a correct picture of such portions of the moon at sunrise or sunset, with their many gradations of tones from the brightest light to

the deepest black. On account of the different chemical and optical action of the rays of light, drawings will always have to supply what is lacking in photography. I was well aware of the difficulty of the undertaking, especially owing to the very unfavorable condition of observation at the observatory at Prague. This observatory is situated in the heart of a smoky town, lighted by gaslight, and is built in the shape of a tower, while the dome can neither be fully opened nor revolved. Observations have to be made through open doors, at a distance of thirty-eight metres above the ground. From March till August, 1884, I used a FRAUNHOFER telescope of three and one-half inches (97.6^{mm}) aperture and a power of 160, on an ordinary mounting. Later I employed a STEINHEIL instrument of six inches (162.6^{mm}) aperture, with powers of 139 and 152 diameters, on a parallactic mounting. While the former had always to be carried out on to the narrow balcony of the tower, the latter was permanently mounted just inside of the south door of the tower, and allowed observations near the meridian only.

The moon can only be followed for three hours with this instrument, so that my observations were limited to certain hours of the night, and also to a certain time. The most annoying circumstance is that the number of good nights is very small, on account of insufficient darkness of the sky, or on account of clouds, so that I am obliged to climb the high tower at all hours of the night. How often have I ascended the 126 steps of the tower, in the small hours of night, at a freezing temperature, to find, upon arriving at the top, that the atmosphere was too unfavorable for drawing, and that my task had to be left unfulfilled. How often the weather has seemed promising at the time the moon was on the meridian, so that a drawing has been commenced, until, suddenly, clouds have put a stop to the work and prevented the completion of the picture. In spite of all this, the pleasure of achievement and the thought of what was yet to be attained, have caused me to forget labor and loss of time, and I have been able to advance, slowly but surely. In using the telescope, I generally draw from one to, at most, two hours without intermission. As I generally employ the same magnifying power, the extent of the picture is only influenced by the amount of detail and the difficulties encountered in the portion to be represented. In case different enlargements are used, the portion of the moon which is chosen must naturally be smaller in proportion to the greater enlargement.

It is desirable to have a cloudless sky during the whole time of

drawing, so that intermissions shall not occur; for the completion of the picture should not be delayed, on account of the changes which take place in the shadows. Similar delays arise from the unsteadiness of the atmosphere; for whenever the object is continually seen indistinctly and obscured, the drawing becomes almost valueless. The first thing to do is to sketch the outlines and larger details of the landscape, as well as those of the shadows, and then to make comparisons to find any improvements which are needed. Then the shading is commenced, and it is desirable to avoid erasing, which should also be avoided in sketching the outlines.

The picture is entirely completed at the telescope, in pencil, so that no additions are required afterwards, as it undoubtedly seems better to represent a small area completely than subsequently to make drawings pleasing to the eye from mere sketches. Immediately, or as soon as possible after the observation, the drawing so obtained is gone over—during four or five hours—with the brush and india-ink, which naturally must be done with the greatest care and attention. Before commencing a drawing, I avoid looking at other representations or charts of the same region, so as not to be influenced by them in any way. It is owing to this circumstance that my drawings give a truthful picture of what a normal eye sees with the instrument and the enlargement employed in a given condition of the atmosphere. It is naturally a great advantage to prepare, in advance, for the drawing, the principal outlines of the object, either by the aid of suitable photographs, or by basing them on one's own previous drawings, in order to be able to devote all the time and attention at the telescope to the shading.

When I first began my drawings of the moon, the STEINHEIL telescope had no driving-clock, and had to be made to follow the moon by moving it by hand. In addition to this, my seat had to be shifted frequently, as well as the oil-lamp, which stood behind my head, the light of which was often insufficient. Furthermore, I had continually to re-sharpen my pencils, to be able to draw the finest details. Add to all this the exertion of reclining, for hours at a time, in an uncomfortable position, and sketching on a board supported only by one's hand, and the fingers becoming numb with cold in winter, and you will agree with me, when I say that all these drawbacks were not calculated to make these tedious labors appear in a pleasant light. Subsequently, however, it became much better. Since July, 1885, I have been in possession of a driving-clock of GRUBB's construction; since September, 1886, I have had a convenient ladder

for observation, with reversible seats, and connected at the side of it was an adjustable table for a lamp, etc. Finally, in April, 1888, I obtained, in place of the oil-lamp, a small incandescent lamp, which is fastened to one's breast, and which always remains in the same relative position to the hand, and which can be lighted or extinguished at will.

The lead-pencils, of which there must be at least twelve different grades, are sharpened beforehand, and a fine file is kept in readiness to sharpen points that have become too dull.

Up to the present time (middle of April, 1890), I have obtained fifty-nine special drawings of craters and landscapes of the moon, situate at the boundary of illumination; of which forty of 1884, 1885, 1886 and 1887 have been published in the astronomical observations of Prague, by the heliographical process. (See the frontispiece.)

Although the heliogravure is by no means equal to the originals in luster and fineness, it, nevertheless, approaches them very closely, and is more to be recommended for such reproductions than photography. My trials in making reproductions in the ordinary lithographic manner also gave good results; but this requires that the engraver on stone should be a real artist, and that the impressions should be made in several tones.

Naturally, everything depends upon the excellence of the reproduction—for the student will blame the observer for anything and everything which is lacking in the published drawing. Even if my charts do not lead to the detection, in the future, of changes on the moon, they, nevertheless, present, I think, a truthful topographical addition to our knowledge of the moon's surface, and at the same time give an indication of what photography should endeavor to attain, as regards sharpness and clearness in pictures of the moon. Should my drawings only serve to stimulate the advance of photography, their object would be fulfilled.

The preceding remarks show that labors of this character can be executed with the most modest means, and it would be very gratifying if many observers, who possess the necessary proficiency in drawing, should cultivate the same field with perseverance. The value of the work does not depend so much on the quantity of the details obtained,—for as regards these the advantage will always lie with the larger instruments,—but on the *completeness* in the representation of what is seen, as parallel studies always form a welcome and valuable control, and as we are still far from having comprised the whole surface of the moon in such plastic drawings of its detail.

On the other hand, how interesting it would be to possess a number of such drawings of the same object for all phases of illumination through a whole lunation, or for the same phase in the different degrees of libration!

The principle should always be, to sketch only when the atmosphere is transparent and steady, and then to reproduce everything that is seen within the specified limits with absolute truthfulness. Particular attention will, therefore, have to be paid to the moon in high declinations, and in case the observations are made on the meridian,—which, of course, is the most favorable point,—we must consider the convenience of the draughtsman; and we must either construct the pier of the instrument sufficiently high, or lower the seat of the observer below the floor. Unfortunately, such arrangements cannot be made at Prague.

PRAGUE, April, 1890.

REFERENCES TO PROFESSOR WEINEK'S DRAWINGS OF THE MOON.

(SEE FRONTISPIECE.)

No. 1. Mare Crisium.
2. Sinus Iridium.
3. Theopilus, Cyrillus.
4. Gassendi.
5. Columbus, Magellan.
6. Tycho Brahe.
7. Fracastor.
8. Archimides.

ON THE AGE OF PERIODIC COMETS.

BY DANIEL KIRKWOOD, LL. D.

Are periodic comets permanent members of the solar system? Is their relation to the sun co-terminous with that of the planets, or has their origin been more recent, and are they, at least in many instances, liable to dissolution? A consideration of certain facts in connection with these questions will not be without interest.

In the brilliant discussions of LAGRANGE and LAPLACE, demonstrating the stability of the solar system, it was assumed (1), that the planets move in a perfect vacuum; and (2), that they are not subjected to disturbance from without. To these restrictions we may add (3), the implied condition that the analysis does not include all forms of

meteoric, cometic, or asteroidal matter which may exist within the system itself. In these respects their conclusions were not final.

That the interplanetary spaces are filled with an ethereal medium had, indeed, been imagined by different astronomers, but of this theory no mathematical test had been afforded by the facts of observation. ENCKE's researches on the motion of his comet have been accepted by many as proof that such a medium actually exists. Should this doctrine be confirmed, the consequence would be obvious.

The fate of BIELA's comet in 1846 directed special attention to cometary physics. Its separation into two parts; the gradual increase of the interval between its members; the return as distinct comets in 1852; the further progress of dissolution beyond the limit of visibility; the resulting star-shower of November 27th—all are now matters of familiar history. Hypotheses, more or less probable, have been offered in explanation, but the significant fact remains—a member of the solar system is lost. How long it had revolved unseen in its eccentric path is unknown, but its history from discovery to dissolution was included in less than one hundred years.

The disappearance of another comet associated with the same cluster has been lately announced. The comet of BRORSEN, discovered in 1846, has a period of about five years and six months. Although its course in 1890 was favorable for its observation, it escaped the most careful search. Should its disappearance prove final, its history as connected with its calculated orbit will comprise but seven perihelion passages.

Twenty-two comets having estimated periods less than that of *Jupiter* have been recorded. Several of these have been seen on but one approach to the sun. Whether the failure of re-detection has been due in any case to a lack of observers, or, as seems not improbable, to perturbation or dissolution, may be a matter of uncertainty. The age of comets—that is, the duration of their visible existence—must depend on their mass and structure, together with their liability to great disturbing influence by the sun and planets. Those with short periods, on account of their frequent subjection to disturbance, will be shorter lived. Those also which are destitute of large or dense nuclei are more easily pulled apart by divellent forces.

"The height of the coma above the nucleus depends on the mass of the nucleus, and gives the measure of its weight, or, more exactly, the least limit of weight which will suffice to maintain such a height of atmosphere.

"The nucleus is usually so closely surrounded by the dense mist

that its diameter cannot be measured; but at times the mist rises, uncovers the nucleus, and leaves it with a sharp stellar aspect. The least diameter determined at such times may be larger than the actual one, but cannot be smaller. From the combination of mass and diameter, the density of the nucleus can be computed. In the case of DONATI's comet, the diameter of the nucleus was perhaps not more than a hundred miles, while the height of the atmosphere extended to eighteen thousand miles. You may be surprised to learn that the corresponding density of the nucleus was at least equal to that of iron. What an unexpected contrast is here presented to the prevalent notions concerning the sun and the comets! The solid sun is reduced by science to the state of gas, while the substance of the ethereal comet is a solid and heavy metal."*

The doctrine that the integrity of comets may be indefinitely maintained by the attractive force of their nuclei may account for the greater stability of ENCKE's comet than that of some others. Though the first discovered of the short-period comets, it shows no special symptoms of disintegration. Well-known phenomena, however, undoubtedly indicate that comets, almost without exception, are gradually losing more or less of their mass. Whatever the nature of the process by which the tails are driven off into space, their lost particles can no more be collected around the same nuclei. Moreover, besides BIELA's comet, already referred to, the initial separation of others, under telescopic view, has been observed by several astronomers. I mention, in particular, the great comet of 1882, whose nucleus, near perihelion, separated into five distinct fragments.

This remarkable comet is perhaps the oldest whose returns are traceable among ancient records.

The orbit is undoubtedly elliptical. The period, according to able computers, is between 700 and 800 years. Dr. MORRISON regards it as identical with the comet 370 B. C.—a comet also reported to have separated into two parts. Its last previous return would thus have occurred in A.D. 1131 or 1132, in each of which years a large comet is recorded. It is a noteworthy fact that this comet belongs to a cluster whose similarity of elements cannot be accidental. Either, therefore, the group existed in space as cosmical clouds before entering the solar system, or we have on a grand scale the partial results of a disintegrating process, the date of whose beginning cannot now be known, but whose continued operation may be traced in the distant future.

* Pierce's Ideality in the Physical Sciences, p. 113.

Is it probable that the number of visible comets within the sun's permanent influence will increase with the age of the system? The fact of frequent cometary dissolutions is no longer doubted, and it is evident that the process, if long continued, must render the original masses invisible, so that in after time the interplanetary spaces must be strewn with dispersed meteoroids. The sporadic meteors now observed in greater or less numbers every clear night may thus be regarded as the scattered debris of ancient comets. If, therefore, we accept LAPLACE'S theory of an extraneous origin, the relative number of comets in the future as compared with the present must depend on the frequency of capture as compared with the rapidity of dissolution.

SOME NOTES ON ASTRONOMY IN SOUTH AMERICA.

By MILTON UPDEGRAFF.*

Having recently returned from a residence of two years and four months (November, 1887, to March, 1890,) at the National Observatory at Cordoba, Argentine Republic, it is with pleasure that I accept the kind invitation of Professor HOLDEN to write a short outline of my impressions of South American astronomy for the *Publications of the Astronomical Society of the Pacific.* I visited the observatories at La Plata and Santiago, and we intended on our return journey to the United States to visit the observatory at Rio de Janeiro, but circumstances rendered it impossible for us to land there. It is said that a fine observatory is also being built near Quito, within three miles of the equator. This, with what I shall say later concerning improvements at La Plata and Santiago, will show that some of the principal Governments of South America, in proportion to their resources, are spending an unusual amount of money on astronomy.

CORDOBA.

The National Observatory of the Argentine Republic is so well known in the United States, through the writings of Dr. B. A. GOULD, its founder and until recently its Director, that a few words as to the recent and present work of the institution will be sufficient.

The principal work of this observatory at present is the formation

* Director of the Observatory of the State University, Columbia, Missouri.

of a visual *Durchmusterung*, like those of ARGELANDER, KRUEGER and SCHOENFELD, to include all stars down to the tenth magnitude between 23½° south declination and the South Pole. The great extent and richness of the region to be covered and the inclusion of all stars down to the tenth magnitude will make the number of stars observed very great. This work is being carried on by Dr. JOHN M THOME, the Director, with one assistant, by means of a four-inch telescope. The observations can be made only when the sky is very clear and the moon below the horizon.

During the two years ending last December, I used the REPSOLD meridian-circle there, observing Dr. AUWERS' "*Catalogue of 480 Fundamental Stars for Observation of Zones between 20° and 80° South Declination.*" These stars were observed completely, five times circle east, and then five times circle west. About 1,200 other stars were observed during the same time for various purposes, consisting largely of stars selected from the *Argentine General Catalogue*, so as to fill up vacant places in the AUWERS list, and observed for the detection of proper motions. I made in all, from November 14, 1887, to December 21, 1889, 11,590 determinations of position, in both right ascension and declination.

My wife, who was formerly Miss ALICE LAMB, of the Washburn Observatory, observed on occasional nights during the first few months, and made 830 observations. Dr. THOME also made about 340 meridian-circle observations; the total number made during this time is about 12,760—an observation in both right ascension and declination being counted once. All these were reduced to apparent place in declination by my wife, and the reductions in right ascension were made by myself. During last July and August I observed the planet *Victoria* and Dr. GILL's list of comparison stars with the meridian-circle, securing twenty-six observations of the planet. Since the completion of the observations on the 480 stars the instrument has been used by my successor, Mr. LESTER C. TAYLOR, in observing certain stars of the *Durchmusterung*.

My observations were made without an assistant, and it is customary there for the observer using the meridian-circle to work alone, making the settings and pointings, reading the microscopes, etc., and recording the same, and meanwhile keeping his weather-eye upon the erratic chronograph, which has a surprising way of stopping short, without any premonitory symptoms whatever. I made many diagnoses, and applied many remedies to cure this malady, which was both chronic and acute, but without entire success. The circum-

polar stars were observed by eye and ear, and those of a list of 54, whose places have been carefully determined, were used for determining the position of the instrument. The time stars used were those of the *American Ephemeris*.

Just previous to our departure last March a fine mounting for the twelve-inch photographic lens formerly used by Dr. GOULD, was received from WARNER & SWASEY. But, unfortunately, while being raised upon the pier intended for its reception, the steel tube fell from a height of several feet and was broken into two parts. Before we left, a local mechanic had succeeded in riveting the parts together.

Cordoba had in 1887 sixty-six thousand inhabitants. The climate is mild and in many respects agreeable, but is debilitating both in winter and summer. For a foreigner, the chief amusement is horseback-riding and traveling in the mountainous country which lies west of the city.

LA PLATA.

The La Plata Observatory is an institution built and maintained by the government of the Province of Buenos Ayres, and is situated at La Plata, the provincial capital, probably the finest city in the Argentine Republic, an hour and a half by rail southwest of the city of Buenos Ayres, near the historic town and seaport of Enseñada. When in Buenos Ayres last March, on my way back to this country, having a few hours at my disposal, I ran down to La Plata, and spent a short time at the observatory. The buildings of the observatory occupy a clear space in a beautiful grove of eucalyptus trees, not far from the residence of the Governor. The site of the observatory is only slightly elevated above high tide in the Rio de la Plata, but the shores of the great estuary are several miles distant.

Although a stranger to him, I was very kindly received by the distinguished Director, M. LE BOEUF, a man of fine presence and possessing a perfect command of the Spanish language. While evidently very busy, he stopped work to conduct me personally through all the principal buildings which were completed or in process of construction. He expressed it as his desire to secure not only the greatest possible solidity in the piers on which the instruments are to be mounted, but also a high degree of rigidity in the instruments themselves. Instead of having a single large observatory building, each instrument is to be mounted in a separate smaller building, in order to secure, as far as possible, isolation from local disturbing causes. The separate buildings are from one to two hundred feet apart, one

story each; their walls and foundations are constructed with the greatest care, of brick, covered outside and ornamented with stucco, in the manner of the country, and the rooms within (as far as completed) are substantially, and even elegantly, finished. Of course, the foundations of the piers are laid very broad and deep in cement—the humid nature of the ground making this necessary. Four of this little village of ten or twelve houses are intended for meridian instruments. Two are unfinished, and one of these is to shelter a large meridian-circle of French make. The other two buildings of this class are completed, and have mounted in them a transit instrument, and a zenith telescope and transit combined.

These instruments are similar to each other and novel in pattern, and have been recently made in Paris from designs by M. LE BOEUF. Although not large instruments, the bed-plates, upright pillars, and, indeed, all parts, are very massively constructed. The exquisitely polished and rounded pivots may be said, without much exaggeration, to approach in size to the telescope tubes. The instruments are fitted with appliances for quick reversal and for otherwise facilitating the work of the observer, and are also nicely finished throughout. The observing-rooms in which these fine instruments are mounted are furnished with all modern improvements. Either gas or electricity may be used at pleasure, and the lamps are provided with ventilating tubes for carrying off the heated air, which would otherwise pour out through the slit and spoil the definition. Such refinements as these are not universally used in South American observatories. These instruments were nearly, if not quite, ready for use, and M. LE BOEUF mentioned, as one of the many uses for which they are intended, the determination of difference of personal equation by simultaneous observation of the same stars.

There are also a building for meteorological and magnetic observations, a large pier for a reflecting telescope, with building to shelter it (not yet finished), a building for a telescope of the *coudé* form (in construction), and several smaller structures, besides the astronomer's house. The latter edifice is a fine one-story house, built around an interior court, in the Spanish style. It contains the private apartments of the Director and other astronomers, and a fine library-room, offices and computing-rooms. On the north front is a wide portico, the roof of which is supported by massive fluted columns. Within it, cut in the main wall of the house, are four niches, intended for life-size statues of NEWTON, GALILEO, KEPLER and LAPLACE, the names of these illustrious astronomers being inscribed above in large gold

letters. On the south front is a smaller portico, having niches for statues of BESSEL and ARAGO.

Having seen this, and much more which I do not now recall (as I took no notes), after bidding good-by to M. LE BOEUF, and thanking him for his kind attention, I hurried away to catch the train for Buenos Ayres, with an impression that this large institution, in process of development under the great difficulties peculiar to the country and location, will, nevertheless, with its ample resources and efficient direction, become a great and useful centre of scientific activity.

SANTIAGO.

During the month of January last, I visited Santiago, the capital of Chili, and sought the place where the American astronomer GILLISS and afterward the German astronomer MOESTA each made a series of observations on the remarkable isolated rock called "El Cerro de Santa Lucia," in the years 1849–1854. In 1854, MOESTA removed the instruments from Santa Lucia to the new National Observatory, which had been erected in the "Quinta Normal," a fine park in Santiago. Since that time the hill or mountain of Santa Lucia has been transformed by the skill of the landscape gardener into one of the most beautiful ornaments that any city in the world can boast. This work involved the blasting away of rock and the building up of walls to such an extent as to render the exact location of any point on the original surface of the mountain difficult or impossible without a knowledge of both the horizontal and vertical co-ordinates from some known point. From MOESTA'S description of the location of the observatory *(Tomo I, Observatorio Nacional de Chile)** and from an engraving, which is the frontispiece of the same book, it is known that the two wooden houses which constituted GILLISS' observatory were

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* I have extracted the following data from this book:

"About Sept. 15, 1852, GILLISS turned over the instruments of the observatory which had become the property of the Chilian Government, and which were valued at 7939 pesos, to MOESTA. The instruments were a meridian-circle by PISTOR and MARTINS, two equatorial telescopes of $6\frac{4}{10}$ in. and 4 in. aperture, a clock, two chronometers and other small instruments. There were also some books and two small wooden houses on Santa Lucia in which the instruments were mounted—in one of them the meridian-circle, and in the other one or both of the equatorial telescopes. The equatorial house had a conical roof and turned about on cannon balls. The houses were situated on two platforms, made by hewing the rock away on the north side of the mountain. The equatorial house was $16\frac{2}{10}$ metres to the south of and $5\frac{2}{10}$ m. higher up than the meridian-circle house. The cistern of the barometer in the meridian-circle house was $58\frac{7}{10}$ m. higher than the center of the Plaza Principal of Santiago, the elevation of this latter point above sea being $559\frac{9}{10}$ m., according to railway levels. Therefore the height of the barometer above sea-level was $618\frac{6}{10}$ m. (= 2029 ft.)."

The horizontal co-ordinates do not seem to be given for either of the houses of the observatory by MOESTA. Whether they are given by GILLISS in his report I do not know. MOESTA disagrees with GILLISS as to the elevation of the site of the observatory.

about half-way up the mountain on the north side. I was naturally somewhat disappointed not to find the place marked in some way, or, rather, not to be able to find the place at all, and on inquiring about it was told that no mark or monument exists on the spot and that the exact place is probably forgotten. On my mentioning this matter to the Hon. PATRICK EGAN, United States Minister to Chili, he said that he considered it an appropriate and desirable thing to have the place found and suitably marked by a tablet or monument. He suggested that, probably, the best way to locate the spot would be to consult the records of the city engineers of Santiago, and, if necessary, to have a survey made. Mr. EGAN also said that if he were furnished with the proper inscription for such a tablet or monument, he would have the exact spot located as accurately as possible, ask the consent of the authorities, and have the place suitably marked. The place can be located approximately, if not very accurately; and the interest which Mr. EGAN takes in erecting a monument there will make it very easy to have the matter properly attended to, provided the Astronomical Society of the Pacific, or any member of it, should feel disposed to co-operate with him for that purpose.*

I also visited the National Observatory of Chili, in Santiago, pleasantly situated in the beautiful botanical garden called the "Quinta Normal." The present Director is M. OBRECHT, formerly of the National Observatory of Paris. He kindly showed us about the institution, and we saw a fine-looking equatorial telescope of ten or twelve inches aperture, and a large new meridian-circle (eight inches, I think,) of French make, which was just being mounted. As I remember it, the dimensions of the "cube" of this instrument cannot be less than fifteen inches. The Director said that he was about to erect additional buildings, and to get more and better instruments.

While we were in Santiago, Mr. EGAN told me that two gentlemen from Peru, belonging to the Harvard College Expedition to the Southern Hemisphere, had lately been in the city, looking for a better location for their observatory than the one they then occupied near Lima. I afterward received, through the kindness of Mr. EGAN, a copy of *El Ferro-carril*, a newspaper of Santiago, for February 19th, in which is printed a letter written by one of these gentlemen, giving an account of their work in South America. I have translated that part of the letter which appears to me to be of interest here. Any

* A paragraph in the New York *Sun* of March 30 announces that Mr. EGAN has recently made arrangements to erect such a tablet.

one who has experienced the hardships incident to life in the more arid parts of South America will appreciate the difficulties under which the Harvard College observers must labor in the Desert of Atacama. It is a very desolate country indeed, that is called a desert in South America:

"DESERT OF ATACAMA, PAMPA CENTRAL, CHILI,
January 29, 1890.

"TO HON. PATRICK EGAN, *Envoy Extraordinary and Minister Plenipotentiary from the United States of America, Santiago de Chili:*

"SIR:—When, some weeks since, I had the pleasure of seeing you in Santiago, you asked me to communicate to you in writing, for communication to our Government and that of Chili, some details with respect to the work of our expedition,—a task which I now undertake with pleasure.

"The astronomical expedition, which is in charge of my brother, S. J. BAILEY, M. A., and in which I have the honor to occupy the position of first assistant, was sent out by the Astronomical Observatory of Harvard University about a year ago, and during this time has been engaged in work of great importance; at first in Peru, and at present in Chili.

"I will first give you a review of what the expedition has accomplished up to the present time, and of the plan of work which it is proposed to accomplish. The work of the observatory at Cambridge is mostly confined to the northern heavens, although some work is done as far south as $-30°$. In order to make observations from this limit to the South Pole, it is necessary to occupy a position south of the Equator. For this purpose the necessary arrangements for establishing an astronomical station at some point in Peru were made during the last six months of 1888 by Professor E. C. PICKERING, Director of the observatory. The expedition was sent out in February, 1889. It has been demonstrated both by the experience of observers of the staff of the Harvard College Observatory, who were stationed on Wilson's Peak, in Southern California, and by the observations of other astronomers, that stations situated on the Pacific Coast, at a certain elevation above the level of the sea, are particularly favorable for astronomical work, because of the transparency of the atmosphere and the prolonged seasons of clear weather which every year affords. After spending some weeks in looking over the country, therefore, the summit of a mountain 6650

feet high was chosen, the mountain being eight miles north of Chosica, Peru, and twenty-eight miles further inland than Lima. The situation was high enough to be always from one to three thousand feet above the fogs of the coast, and far enough from the interior to escape its rains. Two portable houses had been brought from the United States and three other small houses were built on the mountain for the use of the assistants, servants, etc.

"The instruments employed in the observations are a photographic telescope of eight inches aperture, a meridian photometer, with lens of six inches aperture, and various meteorological and other instruments. The mountain peak selected was named Mount Harvard. Observations were begun there on the first of last May. During the following four months more than 1200 negatives were obtained with the photographic telescope. The plan is to cover the firmament four times from 15° to the South Pole: the first time with photographs of an hour's exposure, which will include the spectra of all stars down to about the eighth magnitude; the second time with an exposure of ten minutes, which will give us the spectra of the more brilliant stars; the third time with plates of an hour's exposure, which will give us a map of the southern stars down to the fourteenth magnitude, inclusive; the fourth time with plates of ten minutes' exposure, which will include stars down to about the tenth magnitude.

"The meridian photometer is a double telescope, constructed especially for the purpose of making a more exact determination of the star magnitudes than has yet been attempted in the southern heavens. During the first four months of which we speak, more than twenty-six thousand measures of brightness have been made and recorded. During September and October the sky was so clouded that at the beginning of November Mr. S. J. BAILEY resolved to leave the station at Mount Harvard in charge of the second assistant, while he and I should examine various points along the southern coast to obtain meteorological and other data. We visited the cities of Arequipa, Preno, La Paz, Iquique, Autofagasta, Caldera, Copiapo, Valparaiso, Santiago, and many other points of less importance, but of interest for our work. The chief object of these investigations was to find a locality free from clouds, with an unobstructed horizon, which could be easily reached from the coast by railway. At last we installed ourselves, on the 6th of January of this year, in the Pampa Central, Desert of Atacama, 136 kilometers from Autofagasta, and at an elevation of 1382 meters (4533 feet); and here we have been since that time, working with the meridian

photometer, which was sent to us from Peru as soon as this locality had been selected. Of the twenty-three nights since the date mentioned, twenty-two have been good working nights and seventeen of these perfectly clear. Fogs are entirely unknown here, and it is doubtful whether there is a clearer sky in Chili or in all South America. The admirable clearness of the heavens has greatly facilitated our work. In four nights we have measured the respective magnitudes of 890 stars, and by the 25th of February we hope to complete 6,000 of these observations, all made in the Pampa Central. After that date we shall return to Peru and continue the work at Mount Harvard during the clear season, until next spring, when it is not improbable that the station may be removed to the south, to a locality more exempt from clouds during the summer; perhaps to Arequipa or the Pampa Central itself, where the average number of clear nights during the year seems to be much greater than at Mount Harvard."

The writer goes on to speak of the BRUCE photographic telescope, now being made by the CLARKS, and states that it will undoubtedly be sent to South America after having been used to photograph the northern skies.

On our homeward journey, when among the Windward Islands, going from Martinique to St. Thomas, about April 20th, lat. 15° N., long. 60° W. from Greenwich, we saw the most interesting half of the celestial sphere which is visible at any latitude. There was no wind, the sea was remarkably calm, and (what is most unusual at sea) the evening sky was perfectly clear. To the north was our old friend *Polaris* and the Great Bear, while in the south, standing vertical on the meridian at an altitude of fifteen degrees and sinking slowly downward, was the Southern Cross. To the left of the Cross, just rising above the horizon, were α and β *Centauri*, and to the right *Sirius* and *Procyon*, *Orion* and *Taurus*, while overhead were *Arcturus*, *Regulus* and the planet *Saturn*. The Milky Way spanned the southwestern sky, and in the dense and knotted portion near the Cross showed in deep contrast the black void known as the "coal sack." On the western horizon glowed *Aldebaran*, and out from the faint twilight "the sweet influence of the *Pleiades*" shone upon us, while *Venus* and the thin crescent of the new moon lent their graceful presence to the scene. As to the latter, it was well that she came in the modesty and beauty of youth, for later in life the radiance of her rough red visage would have

blotted out the more delicate beauties of the sky. Later, the Zodiacal Light loomed up conspicuously in the west, but in the east the "Gegenschein," or "counter-glow," was obscured by the combined glory of *Mars* and *Antares*, low down on the horizon, and of *Jupiter*, still below it. I was surprised to see what a monopoly we had of the brighter stars and constellations, and the display was one which would not only fire an amateur astronomer with enthusiasm, but might well overcome the apathy of the most professional of professionals. And thus, after a pleasant acquaintance of two years' duration, we bade farewell to the stars of the southern sky.

CORRIGENDA TO v. OPPOLZER'S "LEHRBUCH ZUR BAHNBESTIMMUNG DER KOMETEN UND PLANETEN."

By Armin O. Leuschner.

I have the honor to communicate to the Society a list of corrigenda to v. Oppolzer's "*Lehrbuch sur Bahnbestimmung der Kometen und Planeten.*" This work is now and will long remain a standard book upon the subjects which it treats, not only for the learner, but also for the practiced computer. It is therefore a matter of some importance as well as of great convenience to have the text freed of misprints and other errata.

The work consists of two volumes; and of volume I, two editions have been printed,—namely, the first edition in 1870, and the second in 1882. Volume II is still in its first edition, and was published in 1880.

Each volume contains a table of the errata detected during the passage of the work through the press. In 1880 Professor v. Oppolzer printed a long list of corrections to volume II. This list may be obtained by application to the publisher (W. Engelmann, of Leipzig). The present paper takes no account of the lists just mentioned, since they are available to every one who owns the work. Since 1880 corrigenda by various astronomers have appeared, from time to time, in the *Astronomische Nachrichten*, and for convenience I have collected these, and they are printed in what follows, with a

reference to the author's name and to the number of the *Astr. Nachr.* in which the errata first appeared. For those errata not so marked I am myself responsible. The present paper was also sent to the *Astr. Nachr.*, but Professor KRUEGER considered that it might better be printed elsewhere.

Owing to the extreme kindness of Dr. F. K. GINZEL, of the Royal Observatory at Berlin, who has been closely connected with the publication of the *Bahnbestimmungen*, and who, upon my request, has revised this paper, I venture to say that few, if any, errors remain in the present series. Dr. GINZEL was in the possession of a number of additional corrigenda which, before Prof. v. OPPOLZER's death, had become known to his assistants. They are printed below among the others, so that the present and Prof. v. OPPOLZER's series contain all errors so far known. I take great pleasure in expressing here my most sincere thanks to Dr. GINZEL for the interest he has shown in regard to this paper.

As volume II was published before the second edition of volume I, the references of the former volume are necessarily to the *first edition* of the latter. In general this produces no serious inconvenience, owing to the "Table of References" prefixed to the second edition of volume I, which gives the pages, etc., of this second edition which correspond to the pages, etc., of the first. In one case, however, a slight inconvenience arises,—namely, in volume II, page 398, where the reader is referred to the first edition of the earlier volume (which, very likely, is not available to him), while in the second edition of that volume the formulæ referred to have been omitted. It seems, therefore, to be worth while to deduce the necessary formulæ here which may be done as follows:

The following is the form of the equation from which the formulæ may be derived (vol. I, 2d ed., p. 65):

$$\frac{kt\sqrt{1+e}}{2q^{\frac{3}{2}}} = \tau\left\{1 - \frac{2}{3}\epsilon\tau^2 + \frac{3}{5}\epsilon^2\tau^4 - \frac{4}{7}\epsilon^3\tau^6 + \ldots\right\}$$
$$+\frac{\tau^3}{3}\left\{1 - \frac{6}{5}\epsilon\tau^2 + \frac{9}{7}\epsilon^2\tau^4 - \frac{12}{9}\epsilon^3\tau^6 + \ldots\right\}, \quad \text{(I)}$$

where $\tau = \text{tang}\ \frac{1}{2}v$ and $\epsilon = \frac{1-e}{1+e}$.

Introducing the quantity θ which is defined by the relation:

$$\text{tang}^2\ \frac{1}{2}v = \tau^2 = \frac{\theta}{\epsilon}, \quad [A]$$

we obtain

$$\frac{k t \sqrt{1+e}}{2 q^{\frac{3}{2}}} = \sqrt{\frac{\theta}{e}} \left\{ 1 - \frac{2}{3}\theta + \frac{3}{5}\theta^2 - \frac{4}{7}\theta^3 + \ldots \right\}$$
$$+ \frac{1}{3}\left\{\frac{\theta}{e}\right\}^{\frac{3}{2}} \left\{ 1 - \frac{6}{5}\theta + \frac{9}{7}\theta^2 - \frac{12}{9}\theta^3 + \ldots \right\} \cdot \quad \text{(II)}$$

Multiplying both sides by $\frac{2(1-e)^{\frac{3}{2}}}{1+e}$ we easily derive

$$\frac{k t (1-e)^{\frac{3}{2}}}{q^{\frac{3}{2}}} = 2\sqrt{\theta} \left\{ 1 - \frac{1}{3}\theta + \frac{1}{5}\theta^2 - \frac{1}{7}\theta^3 + \ldots \right\}$$
$$- 2e\sqrt{\theta} \left\{ 1 - \theta + \theta^2 - \theta^3 + \theta^4 - \ldots\ldots \right\} \cdot \quad \text{(III)}$$

If we now put

$$\left. \begin{aligned} \alpha &= 2\sqrt{\theta} \left\{ 1 - \frac{1}{3}\theta + \frac{1}{5}\theta^2 - \frac{1}{7}\theta^3 + \ldots \right\} \\ \beta &= 2\sqrt{\theta} \left\{ 1 - \theta + \theta^2 - \theta^3 + \theta^4 - \ldots\ldots \right\} \end{aligned} \right\} \quad [B]$$

we finally have
$$\frac{k t (1-e)^{\frac{3}{2}}}{q^{\frac{3}{2}}} = \alpha - e\beta \cdot \quad \text{(IV)}$$

This is the form of equation (I), vol. I, page 65 (2d ed.) in which it appears in the first edition of that volume (page 60). I can now proceed with Prof. v. OPPOLZER's own demonstration:

Since $(1-e)$ is a quantity of the first order, θ must be of the same order since we assumed

$$\theta = \epsilon \operatorname{tang}^2 \frac{1}{2} v \cdot$$

(GAUSS, in his investigations, assumes $\sqrt{\theta}$ to be of the first order.) It can easily be shown that α and β bear the same relation to each other as the arc to the sine. Furthermore, in our case, we shall always have very nearly

$$\alpha = e\beta.$$

Hence, equation (IV) as it stands is not now adapted to solution. Many transformations can be made which all lead to the result that the computation of this difference may be effected with sufficient accuracy by means of the ordinary logarithmic tables. The following transformation, suggested by GAUSS, has the advantage that a quantity B (which will be derived below) may be put equal to unity without introducing errors greater than of the second order (according to GAUSS's determination of errors, of the fourth order).

We shall have

$$\alpha - e\beta = \frac{1-e}{10}(9\alpha + \beta) + \frac{1+9e}{10}(\alpha - \beta).$$

If we put

$$A = 15 \frac{\alpha - \beta}{9\alpha + \beta} \qquad [C_I]$$

we may write

$$\frac{kt\sqrt{1-e}}{q^{\frac{3}{2}}} = \frac{9\alpha + \beta}{10} \left\{ 1 + \frac{1+9e}{1-e} \cdot \frac{A}{15} \right\}.$$

Introducing now

$$B = \frac{9\alpha + \beta}{20\sqrt{A}} \qquad [C_{II}]$$

which quantity, as can be proven, differs from unity by a quantity of the second order only, we obtain

$$\frac{kt\sqrt{1-e}}{2q^{\frac{3}{2}}} = B \left\{ A^{\frac{1}{2}} + \frac{1+9e}{1-e} \cdot \frac{A^{\frac{3}{2}}}{15} \right\}.$$

If we assume that

$$A = \frac{5(1-e)}{1+9e} \cdot \text{tang}^2 \frac{1}{2} w,$$

the equation becomes

$$\frac{kt}{2Bq^{\frac{3}{2}}} \sqrt{\frac{1+9e}{5}} = \text{tang} \frac{1}{2} w + \frac{1}{3} \text{tang}^3 \frac{1}{2} w. \qquad [D]$$

Assuming B to be known, and placing with NICOLAI

$$\theta = A C^2 = C^2 \frac{5(1-e)}{1+9e} \text{tang}^2 \frac{1}{2} w, \qquad [C_{III}]$$

we get

$$\text{tang} \frac{1}{2} v = C \,\text{tang} \frac{1}{2} w \sqrt{\frac{5(1+e)}{1+9e}}, \qquad [E]$$

since

$$\text{tang}^2 \frac{1}{2} v = \frac{1+e}{1-e} \theta.$$

It is not necessary to go any further. After the substitution of the relations [A], [B], [C], [D], [E] in the differential-coefficients on page 398, there remain as unknown quantities only the quotients $\frac{B}{C}$ and $\frac{B}{C^3}$. The expansion of these quantities, however, is given on page 398 *et seq.*

The following *additions and corrections* are to be made to the "Table of References" preceding volume I, second edition.

TABLE OF REFERENCES.

Vol. II.	Reference to the first edition of Vol. I.	Reference to the second edition of Vol. I.
Page 84	Page 47, 48 and 17	Page 54, 57 and 18
" 167	" 28	" 29 ff
" 228	" 81	" 206, 24)
" 229	" 9	" 9, 2)
" 371	" 94	" 268
" 374	" 40	" 44, 1)
" 377	" 71 and 32	" 123 and 35, 30)
" 381	" 84	" 213
" 411	" 81	" 206
" 430	" 109	" 98, 16)
" 432	" 44	" 50
" 464	" 218	" 81
" 473	" 143	" 103, 7)
" 478	" 188	" 82, 8)
" 492	" 106, 3)	" 292, 9)

CORRIGENDA TO VOLUME I (SECOND EDITION).

†Page 12. Line —19, *for* "Ekliptikal coordinaten" *read* "Aequatoreal coordinaten".

* " 29. " — 8, *for* "ϕ" *read* "y".

" 56. " — 1, *for* "tg $(45 + \frac{1}{2}\phi)$" *read* "tg $(45^\circ + \frac{1}{2}\phi)$".

" 71. " — 5, *for* "wol" *read* "wohl".

" 83. " — 1, *for* "$\frac{1}{a}$" *read* "$\frac{1}{-a}$".

* " 95. " +18, *for* "pag. 43" *read* "pag. 44".

* " 97. " + 4, *for* "pag. 104" *read* "pag. 81".

" 111. " —10, *for* "sin ϕ'" *read* "cos ϕ'".

" 111. " — 3 and —4, *for* "cos ϕ" *read* "cos ϕ'".

* " 114. " — 2, in the foot-note after $\pm$ 1.08 *insert* "mit".

* " 117. " — 8, *for* "sin π_0, cos π_0" *read* "sin π_0', cos π_0'".

Page 127. Line — 2, in the first equation *for* "Σ m x" *read* "Σ m y"; in the second *for* "Σ m y" *read* "Σ m x".

" 127. " — 1, the first equation should *read* "$\frac{d^2x'}{dt^2}\Sigma m z = 0$"; the second "$\frac{d^2y'}{dt^2}\Sigma m z = 0$".

" 128. " + 3 and + 4, the equations should *read* "$\frac{d^2z'}{dt^2}\Sigma m x = 0$" and "$\frac{d^2z'}{dt^2}\Sigma m y = 0$".

" 142. " + 1, *for* "(pag. 139)" *read* "(pag. 134)".

* " 146. " + 7, *for* "strenge" *read* "strengen".

" 156. " — 9, *for* "n^2" *read* "n".

* " 158. " —14, *for* "180° — (Π)" *read* "180° — (Π) + ψ".

* " 164. " + 4, after 20) *insert* "nachdem sie mit cos b_1', resp. sin b_1' multiplicirt worden sind".

" 164. " — 1 and —9, *for* "pag. 162" *read* "pag. 145".

* " 199. " — 8, *for* "der Null gleich wird" *read* "den Werth 280° annimmt".

* " 217. " +18, after "ermitteln" *insert* "hierbei ist $\Delta\epsilon$ das Increment der lunisolaren Schiefe in der Zeit ($t_1 - t_0$)".

" 218. " —18, *for* "β" *read* "β_1".

" 221. " — 7, *for* "$\Delta\delta_0$" *read* "$\Delta\alpha_0$"

* " 225. " +13, *for* "cos 2a" *read* "cos 2α".

‡ " 238. " + 6, *for* "9″2365" *read* "9″2370".

* " 241. " +11, *for* "erste Tafel" *read* "zweite Tafel".

* " 241. " +12, *for* "zweite Tafel" *read* "erste Tafel".

* " 242. " —15, *for* "pag. 114, 115" *read* "pag. 118".

* " 246. " — 3, *for* "pag. 120" *read* "pag. 123".

* " 248. " — 9, *for* "pag. 245" *read* "pag. 237, 238".

* " 258. " — 8, *for* "$\alpha - a_0$" *read* "$\alpha - \alpha_0$".

" 276. " +20, *for* "pag. 272" *read* "pag. 276".

" 280. Equation 10) on the left-hand side omit the "minus-sign".

* " 293. Line — 9, *for* "das Zeichen von cos θ erhaelt" *read* "im ersten Quadranten zu nehmen sein wird, da sin ϕ immer positiv ist".

* " 322. " +14, *for* "3″26" *read* "32″6".

* " 338. " +13, *for* "Sonnenort" *read* "Kometenort".

* " 338. " +14, *for* "Aberrationscorretion" *read* "Aberrationscorrection".

" 363. " + 8, *for* "$\frac{dy}{dx}$" *read* "$\frac{dy}{dz}$".

Page 363. Line + 18 and + 19, *for* " x " *read* " z ".
" 363. " + 11, *for* " derselben " *read* " desselben ".
" 370. " − 4, *insert* " $d y_e =$ ".
" 372. " + 1, *for* " 2 ·∫ " *read* " 2 ∫· ".
" 372. " + 15, *for* " $n_{''}$ " *read* " n ".
* " 373. " + 2, *for* " pag. 98 " *read* " pag. 101 ".
" 373. " + 18, *for* " ersten " *read* " erste ".
* " 276. " + 11, } both terms must have the coefficient " $-\frac{1}{2}$ ".
* " 376. " − 4, }
* " 382. " − 13, *for* " $I A_5)$ " *read* " $I A_4)$ ".
* " 412. " + 2, *for* " pag. 72 " *read* " pag. 73 ".
* " 414. " − 4, *for* " cos J " *read* " − cos J ".
" 417. " + 3, omit the word " diese ".
* " 421. " − 14, *for* " die mit x^2 multiplicirten Glieder " *read* " die Glieder 3. Ordnung ".
* " 423. " + 16, both terms must have the coefficient " $-\frac{1}{2}$ ".
* " 439. " + 5, *for* " $\eta_{\prime}$ " *read* " $\eta_{\cdot} - 1$ ".
§ " 478. Argument: 41° 6′ 40″, *for* " 87474 " *read* " 88474 ".
§ " 523. " 615.5 (Fusstafel), *for* " 397.5 " *read* " 307.5 ".
§ " 532. " 148° 30′ 20″, *for* " 00795 " *read* " $\bar{0}0795$ ".
§ " 535. " 155° 24′ 40″, *for* " $\bar{0}6898$ " *read* " 06898 ".
§ " 538. " 160° 28′ 50″, *for* " $8112\bar{0}$ " *read* " 81120 ".
§ " 538. " 161° 32′ 60″, *for* " $9\bar{0}293$ " *read* " 90293 ".
§ " 542. " 169° 30′ 40″, *for* " $0\bar{2}767$ " *read* " $\bar{0}2767$ ".
§ " 586. " 50.0 [col.: Parallaxe], *for* " 88″.17 " *read* " 8″.817 ".
§ " 610. " 77.6 [col.: $(g \cos G)_1$], *for* " $\begin{Bmatrix} +20.17 \\ +\ \ 0.12 \end{Bmatrix}$ " *read* " $\begin{Bmatrix} +20.174 \\ +\ \ 0.127 \end{Bmatrix}$ ".
§ " 610. " 77.7 [col.: $(g \cos G)_1$], *for* " + 0.53 " *read* " + 0.153 ".

‡ Table X_{11}, column ϵ_{11}, and table X d, column B_{11}, are computed with an erroneous value; the resulting error, however, is of no great consequence, since it never exceeds half a unit of the last decimal. It may be taken into account with great accuracy by using in these two columns for the calculation of the secular terms the factor $t = \dfrac{t_o - 1850}{100}$ for the factor $t = \dfrac{t_o - 1900}{100}$.

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* Communicated by Dr. F. K. Ginzel.
† Dr. Paul Lehmann, *Astr. Nachr.* 2810.
‡ Prof. Dr. v. Oppolzer (?), *Astr. Nachr.* 2492.
§ Dr. Prof. Ern. Pasquier, *Astr. Nachr.* 2714.

Corrigenda to Volume II.

Page 10. Line + 4, *for* "$C^{d-p}\left\{\left\{1^2, 3^2, \ldots (2d-1)^2\right\}\right.$" *read* "$C^{d-p}\left\{1^2, 3^2, \ldots (2d-1)^2\right\}$".

" 10. " − 7, *for* "$4\,d\,\delta \sum\limits_{p=0}^{p=\delta} \ldots$" *read* "$4\,d\,\delta \sum\limits_{p=0}^{p=\delta} \ldots$"

" 11. " + 10, *for* "p = d" *read* "p und d".

" 11. " + 14, *for* "$\frac{d}{2^{2d}}$" *read* "$\frac{d}{2^{2d-2}}$".

" 12. " − 7, *for* "$2^{(2d-p)}$" *read* "$2^{2(d-p)}$".

" 15. " − 9, *for* "wie dies in Gleichung 4)" *read* "wie dies in Gleichung 4), pag. 9".

" 15. " − 7, *for* "$m\,f\,(a + [i + \frac{1}{2}]\,w)$" *read* "$m\,f^1\,(a + [i + \frac{1}{2}]\,w)$".

" 15. " − 4, *for* "$f\,(a + [i + \frac{1}{2}]\,w$" *read* "$f\,(a + [i + \frac{1}{2}]\,w)$".

" 18. " − 8, *for* "$-\frac{C^3\{1^2, 5^2\}}{2^6}$" *read* "$-\frac{C^3\{1^2, \ldots 5^2\}}{2^6}$".

" 32. " − 8, *for* "$d\,l = d\,(a + [i + n]\,w) + d\,(a + [i + \frac{1}{2} + m]\,w)$" *read* "$d\,l = d\,(a + [i + n]\,w) = d\,(a + [i + \frac{1}{2} + m]\,w)$".

" 34. " + 3, *for* "$\sum\limits_{a=1}^{d=\infty} \ldots$" *read* "$\sum\limits_{d=1}^{d=\infty} \ldots$".

" 34. " + 7, *for* "$C^{d-p}\left\{1^2, 3^2 \ldots (2d-1)^2\right)$" *read* "$C^{d-p}\left\{1^2, 3^2 \ldots (2d-1)_2\right\}$".

" 35. " + 13, *for* "B^1" *read* "B_1".

" 39. " − 3, *for* "$\begin{matrix} n^3 \\ 1.2.3 \end{matrix}$" *read* "$\frac{n^3}{1.2.3}$".

" 41. " + 14, *for* "$\int^{a + [i + \frac{1}{2} m]\,w} f\,(l)\,d\,l$" *read* "$\int^{a + [i + \frac{1}{2} + m]\,w} f\,(l)\,d\,l$".

" 44. " + 13, *for* "der Formeln" *read* "den Formeln".

" 45. " − 9, *for* "benütze" *read* "benützen".

" 47. " − 8, *for* "$^1f\,(a + \frac{1}{2}\,w)$" *read* "$^1f\,(a - \frac{1}{2}\,w)$".

" 50. " − 13, *for* "aus den für 21)" *read* "aus den für 7)".

" 55. " − 13, *for* "$J_1 = \int^{a+iw} f\,(a + [i + n]\,w)\,d\,l$" *read* "$J_1 = \frac{1}{w}\int^{a+iw} f\,(a + [i + n]\,w)\,d\,l$": the use of Formula B_1, page 35, is then clearer. Compare equations 2) and 4) page 32.

Page 56. After the first equation insert the number "34)".

" 59. Line + 2, *for* "$\frac{1}{2}\,{}^{1}f(a - \frac{1}{2}w]$" *read* "$\frac{1}{2}\,{}^{1}f(a - \frac{1}{2}w)$"

" 59. " − 6, *for* "$P_1^3(m)\, f^{III}(a - \frac{1}{2}w)$" *read* "$P_2^3(m)\, f^{III}(a - \frac{1}{2}w)$".

" 61. " + 6, *for* "$\log f(a + iw)$" *read* "$\log f^d(a + iw)$"

" 70. " + 13, *for* "$\frac{k\,m_1}{\rho^2}$" *read* "$\frac{k^2\,m_1}{\rho^2}$".

" 82. } The numerical values of the constants are somewh
" 86. } different from those of the second edition of vol. I
See preface to same.

" 99. Line + 1, *for* "Rech nung" *read* "Rech-nung".

" 147. " − 8, *for* "$\frac{a_0^2 \cos\phi_0}{((r^2))}$" *read* "$\frac{a_0^2 \cos\phi_0}{((r))^2}$".

" 150. " − 3, *for* "$\tau' t \ldots$" *read* "$\tau' \ldots$".

" 151. " − 17, *for* "$[P_{-1} + P_0)$" *read* "$(P_{-1} + P_0)$"

" 151. " − 7, *for* "$(12\gamma - a\alpha)$" *read* "$(12\gamma + a\alpha)$".

" 153. " + 4, *for* "$\frac{d^2 \nu_{+1}}{dt^5}$" *read* "$\frac{d^2 \nu_{+1}}{dt^2}$".

" 154. " + 13, *for* "$f^{I}(a - \frac{1}{2}w]$" *read* "$f^{I}(a - \frac{1}{2}w)$".

" 159. " − 15, equation 7). Strictly speaking, we cann here write "cos u′" for "cos u", sinc these formulæ are general, and th special case: cos J nearly = 1 is no as yet taken up.

" 165. " − 8, *for* "$\frac{z}{(r)}\frac{dz}{dt}$" *read* "$\frac{z}{((r))}\frac{dz}{dt}$".

" 174. " + 7, *for* "ω" *read* "ω_0".

" 175. " + 8, *for* "$\int\int^{a+iw} f(x)\,dx^2$" *read* "$\int\int^{a+[i\pm 1]w} f(x)\,dx^2$" (cf. page 233).

" 179. " + 4, *for* "$f^{III}(a - \frac{1}{2}\omega)$" *read* "$f^{III}(a - \frac{1}{2}w)$".

" 256. " − 7, *for* "mehr minder" *read* "mehr ode minder".

" 292. " − 7, *for* "$\left(\frac{2}{3}\right)^2\int \ldots$" *read* "$\frac{(2)^2}{3}\int \ldots$".

" 301. " − 7, *for* "die Quadrate der Præcisionen" *rea* "die Præcisionen".

" 308. " − 8, *for* "se" *read* "es".

" 314. " + 3, 4, 16, better "n" *for* "v".

" 326. " − 1, *for* "$(\alpha\beta)$" *read* "$[\alpha\beta]$".

* " 340. In the line $\log\frac{[c\,d_2]}{[c\,c_3]}$ *for* $\left\{\begin{matrix}\frac{[cd_2]}{[cc_3]}[cl_3] \\ \frac{[cd_3]}{[cc_3]}[cf_3]\end{matrix}\right\}$ *read* $\left\{\begin{matrix}\frac{[cd_2]}{[cc_2]}[cl_2] \\ \frac{[cd_2]}{[cc_2]}[cf_2]\end{matrix}\right\}$

Page 343. In the second elimination-equation from bottom, *for* "064255" *read* "0.64255".

" 362. Line − 4, *for* "mehr minder" *read* "mehr oder minder".

" 383. Line + 5, *for* "Maasse" *read* "Masse".

† " 392. " − 6, *for* "$\delta\pi = p \sin(N - \pi_0) + \frac{1}{2} p^2 \sin 1'' \sin(2N - \pi_0) + ..$" *read* "$\delta\pi = p \sin(N - \pi_0) - \frac{1}{2} p^2 \sin 1'' \sin(2N - \pi_0) + \ldots$",

" 393. " + 3, *for* "Δe" *read* "δe".

" 394. " −16, *for* "$C = 180 - i$" *read* "$C = 180 - i'$".

" 408. " +15, *for* "§ 11" *read* "§ 2".

" 414. " + 4, *for* "$\cos \delta\delta a : \sin i' \delta ☊$" *read* "$\cos \delta\delta a : \sin i' \delta ☊'$".

" 431. " − 6, *for* "das ist" *read* "dass ist".

" 431. " − 3, *for* "$h' = \left(r_0 \frac{\delta r_0}{d\tau}\right)$" *read* "$h' = \left(r_0 \frac{d r_0}{d\tau}\right)$".

" 431. " − 1, *for* "$\frac{\delta h'}{d x_0}$ und $\frac{\delta h'}{d \xi_0}$" *read* "$\frac{\delta h'}{\delta x_0}$ und $\frac{\delta h'}{\delta \xi_0}$".

" 432. Equation 15) *for* "$\frac{\delta h'}{d x_0}$" *read* "$\frac{\delta \overline{h'}}{\delta x_0}$".

" 435. Line +13, *for* "$\Sigma (x_n)^2$" *read* "$\frac{1}{2} \Sigma (x_n)^2$".

" 455. " −10, *for* "A)" *read* "A_1)".

" 458. " −18, *for* "ξ" *read* "ξ_0".

" 458. " −17, *for* "in B)" *read* "von B) in A_1)".

" 458. " −12, *for* "x" *read* "x".

" 458. " − 9, *for* "pag. 368" *read* "pag. 369".

" 459. " − 1, 2, 4, 5, *for* "$d\xi$ und dx" *read* "$\delta\xi$ und δx".

" 460. " + 1, *for* "$d\xi$ und dx" *read* "$\delta\xi$ und δx".

" 462. " + 1, *for* "17.96" *read* "47.96".

" 463. Column $\cos \beta \delta\lambda$, first line, *read* "+ 0″04" and column $\delta\beta$, second line, *read* "− 0.70".

" 466. " + 1, *for* "darf" *read* "dürfen".

" 469. " + 3, *for* "$\frac{(r + r')^{\frac{3}{2}}}{a}$" *read* "$\frac{(r + r')^{\frac{3}{2}}}{a^2}$".

§ " 488. " − 6 and −7, on the right-hand side of the equations, *for* "$\left(\frac{\delta \lambda_1}{\delta x}\right) \Delta x$ and $\left(\frac{\delta \lambda_2}{\delta x}\right) \Delta x$" *read* "$\left(\frac{\delta \beta_1}{\delta x}\right) \Delta x$ and $\left(\frac{\delta \beta_2}{\delta x}\right) \Delta x$".

" 491. " + 9, *for* "tag δ" *read* "tang δ".

LICK OBSERVATORY, April, 1890.

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* Communicated by Dr. F. K. GINZEL.

† Prof. Dr. A. SEYDLER, *Astr. Nachr.* 2856.

§ T. HACKENBERG, *Astr. Nachr.* 2899.

POSTSCRIPT.

After the preceding corrigenda were in print, a list of errata in volume II was published by Lieutenant-General J. F. TENNANT, R. E., F. R. S., in the *Monthly Notices* of the R. A. S. (Vol. L, No. 7). The following of these I have verified, and they are not contained in the present list, or in any previous one, so far as I know:

Page 11. Line +16, *for* "$C^{d-p}\left\{1, 2, 3, \ldots d-1\right\}$" *read* "$C^{d-p}\left\{1^2, 2^2, 3^2, \ldots (d-1)^2\right\}$".

" 110. Log. $S_{(2)}$, Oct. 27, *for* "$1_n861612$" *read* "$2_n861612$".

" 110. " $S_{(2)}$, Dec. 6, *for* "$0_n045547$" *read* "$0_n075547$".

" 163. Line − 4, *for* "$\dfrac{\sin\frac{1}{2}(E-E_0)}{\frac{1}{2}(E-E_0)}$" *read* "$\dfrac{\sin\frac{1}{2}(E-E_0)}{\frac{1}{2}(E-E_0)\sin 1''}$".

The remaining errata given by General TENNANT have either been previously printed or else I find myself unable to subscribe to their correctness.

While engaged in revising this list, I noticed the following additional errata in the computations, as printed on pages 110 and 111:

Page 110. Log z, Jan. 15, *for* "$9_n148099$" *read* "9.148099".

" 110. " z, Dec. 6, *for* "$9_n150349$" *read* "9.150349".

" 110. " z, Oct. 27, *for* "9.147436" *read* "9.148436".

" 111. " fqz, Oct. 27, *for* "$1_n733151$" *read* "1.733151".

" 111. $\Delta\Sigma$ (Z), Oct. 27, *for* "− 0.06" *read* "+ 0.62".

In *Astr. Nachr.*, No. 2968, cand. astr. H. KLOOCK, of Bonn, calls attention to a statement in volume I, regarding diurnal aberration, which is too general. The simplest way to remove the ambiguity is as follows:

Page 111. Line −17, *after* "Beobachtungen" *insert* "falls dieselben nicht gerade absolut sein sollten."

LICK OBSERVATORY, August, 1890.

ELEMENTS OF COMET COGGIA (JULY 18, 1890).

BY ARMIN O. LEUSCHNER.

From the Marseilles observation of July 19 and two others made at the Lick Observatory by Mr. W. W. CAMPBELL on July 22 and 23, the following elements of Comet COGGIA (July 18, 1890) have been computed:

$$T = 1890, \text{ July } 8.5983 \text{ G. m. t.}$$
$$\left.\begin{aligned} \omega &= 85^\circ\ 46'.0 \\ \Omega &= 14^\circ\ 25'.6 \\ i &= 63^\circ\ 14'.3 \end{aligned}\right\} \quad \text{M. Equinox } 1890.0$$
$$\log q = 9.88404$$
$$\text{O} - \text{C}: \quad \Delta\beta = +0'.1, \quad \Delta\lambda \cos\beta = +0'.1$$

LICK OBSERVATORY, July, 1890.

ELEMENTS OF COMET DENNING (JULY 23, 1890).

BY ARMIN O. LEUSCHNER.

The first three observations of Comet DENNING (July 23, 1890), secured at the Lick Observatory by Mr. E. E. BARNARD on July 25, 26, 27, are represented by the following orbit:

$$T = 1890, \text{ Sept. } 22.011 \text{ G. m. t.}$$
$$\left.\begin{aligned} \omega &= 169^\circ\ 28'.1 \\ \Omega &= 106^\circ\ 44'.1 \\ i &= 97^\circ\ 10'.5 \end{aligned}\right\} \quad \text{M. Equinox } 1890.0$$
$$\log q = 0.06548$$
$$\text{O} - \text{C}: \quad \Delta\beta = 0'.0, \quad \Delta\lambda \cos\beta = 0'.0$$

LICK OBSERVATORY, July, 1890.

From Mr. BARNARD's observations of July 25, August 3, and August 12, I have deduced the following new elements of Comet DENNING (1890, July 23):

$$T = 1890, \text{ Sept. } 24.4824 \text{ G. m. t.}$$
$$\Omega = 99^\circ\ 56'\ 27''.9$$
$$\omega = 162^\circ\ 45'\ 59''.9$$
$$i = 98^\circ\ 58'\ 25''.8$$
$$\log q = 0.101606$$
$$\text{O} - \text{C}: \quad \Delta\lambda \cos\beta = +9''.5, \quad \Delta\beta = +5''.2$$

LICK OBSERVATORY, August 14, 1890.

A SUGGESTION OF A WAY TO FORWARD OUR KNOWLEDGE OF THE ASTEROIDS.

BY REINHOLD SCHMIDT, ZOERBIG, GERMANY.

[Reprinted by special request of the author.*]

The year 1890 is likely to mark quite an important departure in the history of asteroidal discoveries, and in one sense, unfortunately, a departure not for the better.

As announced in the astronomical almanac of the Imperial Observatory of Vienna for 1890, the great number of the already known asteroids, and, more than that, their rapid increase, have made it an impossibility for the Berlin Computing Bureau to keep up the constant work of furnishing the necessary data for the small planets, for upon this institution the duty of doing this exhaustive work has thus far depended. For a number of years past, accurate ephemerides have been limited to the newly-discovered asteroids and to those whose orbits are still affected by a considerable uncertainty, in order to facilitate the observations still required for a correction of their elements. Of the older and better known asteroids, however, only very rough ephemerides have been given, simply for the purpose of enabling one to decide whether a movable body attracting our attention be a planet already known or a new one; but an accurate calculation of the perturbations to which they are subjected, and a correction of their orbital elements by later observations has been omitted. The result is naturally this, that, with a few exceptions, we do not at the present time know the orbit of any asteroid with such accuracy as the state of science demands — with such precision as would allow us to carry on theoretical investigations, such as, for instance, the determination of Jupiter's mass, etc. To put an end to this very unsatisfactory condition of affairs, the editors of the *Berliner Jahrbuch* have concluded to begin, first of all, a more thorough treatment of the existing material for such planets as, for theoretical or other reasons, are of particular interest, while the remaining ones, and the later discoveries, will be considered only in so far as they may be of value for other important astronomical investigations. According to these principles predictions will be furnished, from this time on, only for such asteroids as:

* English translation from *Die Natur* (April 1890), by OTTO VON GELDERN.

(1) Approach near the earth, and are, therefore, particularly adapted to determinations of parallax;

(2) Approach near to *Jupiter*, and are useful for determining its mass;

(3) Are remarkable for a period having a closely commensurable ratio to that of *Jupiter;* it being known that such orbits are of the greatest importance in the theory of absolute perturbations;

(4) Attain considerable brightness, and are, therefore, of value in photometric work.

If, in the future, the computations are limited to this category of asteroids, it will probably be possible for the next two or three years only to tell with absolute certainty whether a newly discovered moving star be a planet already known or an unknown one; but later on, when the number of these incompletely determined asteroids shall have reached several dozens, it will be simply impossible.

If these conditions remain as stated by the authority here quoted, it is evident that research in the field of planetoidal discoveries will have received its death-blow. For what discoverer would be willing to take the trouble and spend the time in searching for asteroids, if in case of a discovery he would not be able to tell whether he had found a new body or not? The present discoverers would, in the nature of things, turn to other fields of astronomical labor, or would limit themselves to observations upon those asteroids falling within the four groups mentioned, occasionally looking up one of the other now known and completed planetoids for a general control.

But this would undoubtedly be a step backward, and greatly to be regretted. Every planetoidal discovery, even if of no other value, increases our knowledge of the solar system, and from the mere number and their existence—that is, from the statistics of the known asteroids—very important conclusions have already been drawn. Posterity would find it difficult to understand why the discovery of asteroids should cease at the end of the nineteenth century, when the optical means are still adequate for a long time to come, and the powers of a PALISA, PETERS, LUTHER, CHARLOIS, and others, are still available for such a service; when there is no other reason for the interruption of this work than that the computer failed to furnish the necessary calculations.

Against the Berlin Computing Bureau, as far as it concerns that institution, nothing can be said, for the curtailment announced in this work had become an absolute necessity. And, aside from this, it is to be noted with satisfaction that, in certain directions, a deeper

knowledge of the asteroids, etc., will be gained by this decision. But would it not be possible to take up this constantly required work in other quarters according to the principle of a division of labor?

In the old world it is more than likely that all larger astronomical institutes have their set plan of work for years and decades to come, to which such a considerable amount of extra and continuous labor could not well be added. Involuntarily we turn our face to North America, where new and extensive astronomical institutions, generously endowed with instruments, money and assistants, are constantly created. *Could not one of these make it a special object to furnish regular computations, accurate enough for all purposes of the discoverer at least, of those planetoids that are now left unconsidered in Berlin, and to publish them in almanacs, etc., for coming years?* It would seem as though this were a good work of considerable importance — a work which would meet with greater approval by many than, for instance, the effort to eclipse the gigantic telescopes of the day by the creation of a still larger one. At all events, the idea may deserve the attention of those interested on "the other side."

ON THE PHOTOGRAPHS OF THE MILKY WAY MADE AT THE LICK OBSERVATORY IN 1889.

By E. E. Barnard.

It seems desirable to give a brief description of the photographs of the Milky Way made by me at the Lick Observatory in 1889, and to call attention to their special and important points which might otherwise be overlooked by those not familiar with celestial photography, and thus their value be under-estimated for the purpose for which they were made. It was intended to show, as far as possible by photography, the wonderful and complex structure of the Milky Way.

One very important feature, and one which must not be overlooked, is that these are the only photographs ever made, here or elsewhere, which show at all the true Milky Way.

The structure of the Milky Way is invisible in the telescope because of the limited field of view; for we see, comparatively, only a few of the individual stars whose combined light illuminates the sky and aids in giving the clouded appearance which is so conspicuous

to the naked eye. And here it may not be unimportant to remark that the vast majority of the stars whose light goes to make up the true Milky Way cannot be seen in any telescope ever constructed—they are individually so small and faint. It is therefore impossible to obtain any idea of the structure of the Milky Way from telescopic observations alone, because of the limited field and the faintness of the smaller stars.

In a photographic experience of twenty-five years, I have never seen anything more deceptive to photograph than the Milky Way. From some of the first experiments, made with a small camera, it seemed impossible to photograph it, the sensitive plate apparently picking out only the individual points of light. To the eye, the Milky Way is a bright and conspicuous object, and at first it would seem as if an impression of it would be made with a comparatively short exposure. A few experiments, however, showed the hopelessness of this. If we consider that this nebulous appearance of the sky is due to an infinite number of invisible points of light, and not to an illuminated background such as nebular light, it would seem that a photograph of the true Milky Way would be impossible. It is, in fact, by no means easy—for the exposure must be very long, and the instrument must be watched and kept constantly fixed on some one star of the proposed picture every moment for several hours; and when all this is properly done, the plate requires the utmost delicacy of treatment in developing.

The possibility of photographing the true Milky Way at all is explained by the following theory:

If we look at a dense cluster of stars, too closely packed for the instrument to distinguish the stellar points, it appears as a nebula, or is continuous in its light. Increase, now, the dimensions of the telescope, and the nebulosity disappears and we see each individual point of light. In the Milky Way the stars are crowded together by distance. If we could approach it, which we can do, in a sense, by the telescope, we should separate the stars in proportion to the lessening of our distance, or the size of our telescope. The eye is too feeble to pick out the individual stars of the Milky Way, or to separate them; it therefore perceives only a nebulous or clouded appearance, and is really impressed by a *quantity* of light which is made up altogether of individually invisible sources. The sensitive plate is not thus deceived, for its action depends upon the *intensity* of the light, and it therefore picks out each individual point, if the lens is good.

Applying these remarks now strictly to the Milky Way, we should

find that by continuing the exposure long enough, the multitudes of stellar points which form the cloud masses would come into view so thickly on the plate as to blend together and form a more or less continuous surface, thus giving the exact cloud structures as they exist in the heavens. Now, a lens of the same light-ratio, but giving a larger scale, with the same exposure as the foregoing, would show only a great number of separate stars, without indicating anything of the cloud structure proper. A much longer exposure would, therefore, be required to bring other stars into view sufficiently numerous to fill the spaces before the true structure would again appear. We should, therefore, finally come to a point, by increasing our scale, at which no exposure possible would be sufficiently long to reproduce the true Milky Way. By increasing the scale beyond a certain limit, the characteristic structure is lost.

But there is also a certain point where the lens cannot show the true structure, because of the smallness of scale and the deficiency of penetrating power; that is to say, a very small lens would not show the structure with sufficient distinctness to be of any special value. The photography, therefore, of the true Milky Way must be confined to instruments of medium dimensions—with large apertures and small focal lengths—until our plates can be made much more sensitive, or the exposures extended through several nights.

The splendid pictures made by the HENRY brothers at Paris, considered as photographs of the stars, have never been equaled by any other astronomers with any telescope. The stars are wonderfully sharp and round, and a print from one of their negatives is almost as perfect as if made from a steel plate. I have before me now one of their photographs of a portion of the Milky Way in *Cygnus*. It is a perfect specimen of the photographic art, and shows a vast number of stars on a black sky; but there is no trace, or even a suggestion of the Milky Way proper, and it might fairly refer to any other portion of the heavens than the Milky Way save for the number of stars depicted. This picture represents the finest work yet done in stellar photography.

In the photographs made with the six-inch portrait lens, besides myriads of stars, there are shown, for the first time, the vast and wonderful cloud forms, with all their remarkable structure of lanes, holes and black gaps and sprays of stars. They present to us these forms in all their delicacy and beauty, as no eye or telescope can ever hope to see them; while the individual stars, near the middle of the plates, are as round and perfect as are those made at Paris.

The lens used in this work was of the ordinary portrait combination, having an aperture of six inches and a focal length of thirty-one inches. This lens, attached to a box of the proper size, was firmly strapped to the tube of the six-and-a-half-inch equatorial. As no driving clock is so perfect as to keep a telescope moving with the apparent motion of a star for any considerable length of time, it was necessary to keep the eye fixed upon a star bisected by cross wires in the eye-piece, and to correct the motion of the telescope by hand with the slow-motion rods throughout the long exposures. One of these exposures thus made,—the longest,—was five hours and ten minutes.

I have been able, so far, to make negatives of only three portions of the Milky Way with this lens, as it has not been available since last summer.*

The most wonderful of these Milky Way pictures is the one in the constellation of *Sagittarius* (R. A. $17^h\ 56^m$, Dec. South 28°), a region which I specially selected as possessing the most intricate and complex structure of any portion of the Milky Way above our horizon. This was given an exposure of $3^h\ 7^m$.

The only other celestial photographs that I have made were also taken with the portrait lens. They are the Great Nebula of *Andromeda*, exposure $4^h\ 18^m$; the *Pleiades* and the *Merope* Nebula, $1^h\ 15^m$; the Trifid Nebula, $4^h\ 5^m$; Davidson's Comet, $1^h\ 30^m$. From the short focus of this lens, these nebula pictures are necessarily on a small scale (1 in. = 1°.8.)

Although these pictures of the nebula are very perfect, yet they must not be compared with the photographs of the nebulæ taken by Mr. ROBERTS and Mr. COMMON without proper consideration of the instruments that made them. Mr. ROBERTS works with a reflector of twenty inches diameter and one hundred inches focus; while Mr. COMMON has used a thirty-six-inch reflector, and now is using a telescope five feet in diameter. The HENRY brothers employ a photographic telescope with a lens thirteen inches in diameter. Allowing for the difference in the size of the instruments, my photographs of the *Andromeda* Nebula, etc., compare most favorably with anything made by these astronomers. The picture of the *Andromeda* Nebula, made with the portrait lens, though on so small a scale, shows nearly every detail that is on Mr. ROBERTS' photograph, acknowledged to be the best photograph ever taken of a nebula; and, while it is

* This lens is now having a mounting made for it, which Hon. C. F. CROCKER has presented to the Observatory.

necessarily lacking in what is due to scale, it shows the wonderful structure of the region in which the Great Nebula is situated as nothing else has ever shown it.

Some of the above pictures made with the portrait lens have been beautifully reproduced in *Knowledge* of July and August (A. C. RANYARD, ed., 67 Chancery lane, London, W. C.). The July (1890) number of that journal has a full-page reproduction of the Milky Way picture in R. A. $17^h 56^m$, Dec. — 28°, done in an admirable manner by the Direct Photo-Engraving Company, of London, and is accompanied by an article by the editor on the singular features shown on the photograph.

MT. HAMILTON, August, 1890.

BLACK TRANSIT OF *JUPITER'S* SATELLITE IV.

BY C. B. HILL.

While entertaining a party of visitors at the Chabot Observatory on August 13, I turned the 8.5-inch equatorial on *Jupiter*, and noticed that the fourth satellite, then in transit, was outlined against the apparent lower limit of the N. belt as a perfectly black spot, even more pronounced in its blackness than is the usual shadow.

This was at 9:10 P. M. Pacific standard time; and as soon as the visiting party had left the observatory, I went to the telephone office, and notified Professor BARNARD at the Lick Observatory, knowing him to be especially interested in this class of phenomena, only to find (as might have been expected) that this event had not escaped the astronomer in his nightly comprehensive sweep of the heavens.

Resumed observations 10:10 P. M. Satellite IV, equally black; seemingly internally tangent to N. line of belt, and followed by two little dark spots. Under highest powers (400, 500), satellite still remained strikingly black, and to my eye *perfectly circular*, while the details of the belts, and all trace of the other dark spots were lost in the indistinct vision.

Made sketch of the planet 10:30–10:45. First dark spot closing up on satellite, on account of the rapid rotation of planet. Image of IV now seemed to me rather grayer. Consulted ephemeris, and found that the entry of shadow and the leaving of the last train for the city

would be dangerously close together, but I compared my watch with the observatory time, and made ready for a hasty departure.

IV. Shadow Ingress (August 13).

		h.	m.	s.	
I contact, well on . .	=	11	1	43	P. s. t.
Half on (?) *too early* .	=	11	3	58	
II contact, suspected .	=	11	7	58	
do. established .	=	11	9	33	

A rapid glance at the images of satellite and shadow confirmed the opinion that the former had *slightly* diminished in blackness, it being now a shade the lighter. The preceding dark spot on belt had nearly disappeared under the N. limb of the satellite.

It seems time for some competent hand to collate the accounts of these anomalous transits and endeavor to evolve something definite out of the various conjectures of their cause. If we suppose (1) that there is a difference in the *albedo* of the two hemispheres of IV, and (2) that the rotation of this satellite is equal to its period of revolution, a tabulation of all the dark and partly dark transits should, I imagine, either definitely affirm or break down these hypotheses.

Jup. Sat. I, Occultation Disappearance (August 15).

		h.	m.	s.	
I contact (?)	=	9	21	58	P. M.
do. established . .	=	9	22	44	
Half gone (?)	=	9	24	19	
Still visible	=	9	26	11	
Trace	=	9	26	30	
Gone	=	9	26	42	

Times recorded by Mr. HENDERSON.

August 15, 1890, P. M.

AWARD OF THE DONOHOE COMET MEDAL.

The Comet Medal of the Astronomical Society of the Pacific has been awarded to W. F. DENNING, Esq., F. R. A. S., of Bristol, England, for his discovery of Comet *c* 1890, on July 23, at $11^h\ 35^m$, Greenwich mean time. This is the second comet discovered by Mr. DENNING.

The Committee on the Comet Medal,

EDWARD S. HOLDEN,
J. M. SCHAEBERLE,
CHAS. BURCKHALTER.

NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

ON THE ROTATION TIME OF THE PLANET *VENUS* [BY PROFESSOR G. V. SCHIAPARELLI].

Professor SCHIAPARELLI has printed in the *Rendiconti* of the *Royal Lombardic Institute* a series of five articles entitled "Considerations on the Rotation of the planet *Venus*." In the last of these notes the conclusions arrived at are summarized in a series of theses, somewhat as follows:

"1. The rotation of *Venus* is exceedingly slow, and takes place in such a way that the situations of the markings on its surface, with respect to the position of the terminator between the illuminated and the dark portion of the planet, do not seem to suffer any appreciable change even in the duration of an entire month.

"2. From the few definite observations of these markings which it has been possible to collect, the most probable result is that the planet makes one rotation in 224.7 days,—that is to say, in a period exactly equal to the duration of its sidereal revolution about the sun; and that this rotation takes place about an axis almost exactly perpendicular to the plane of the orbit.

"3. The possibility of a certain variation of the true elements of rotation from those above given, is not entirely excluded by the observations. Such variations might attain, so far as the time of rotation is concerned, values of some weeks more or less, so that, strictly speaking, a period not less than six months and not more than nine might reconcile the data. As to the direction of the axis, a deviation of ten or fifteen degrees from the perpendicular to the orbit is still possible.

"4. A rotation period of approximately twenty-four hours, more or less, is entirely excluded. The observations of DOMENICO CASSINI agree better with a period of 224.7 days than with one of twenty-four hours; the rotation time of $23^h\ 21^m$ (or 22^m) proposed by JACOPO CASSINI, which SCHROETER and DE VICO considered to be confirmed by their observations, is the result of a series of fallacious arguments, and of vicious circles of reasoning.

"5. The rapid variations in the aspect of the planet (and specially in the horns of its crescent), which have been frequently noticed

to repeat themselves in a period of about twenty-four hours cannot be adduced to support the hypothesis of a rotation of about one day. Such variations arise from atmospheric causes, which tend to repeat themselves in a daily period.

"6. BIANCHINI's observations were made on markings which were too poorly defined to give satisfactory results, and the alterations of aspect which he attributed to rotation were due to changes in the atmosphere of the planet itself.

"7. In the more southern regions of the planet there sometimes occur formations of markings, rather well-defined, clear and dark, which (so far as could be judged from the little which was seen of them) seem to reappear from time to time under identical aspects, and would thus lead us to suppose a relation of such phenomena with forces having fixed situations on the surface of *Venus*. Continuous and diligent observations of these appearances made with instruments adapted to the purpose would probably give an exact and definitive solution to the problem of the rotation of *Venus*.

"8. Important, likewise, is the study of certain very small markings, bright, spherical and well-defined, surrounded, or sometimes flanked, by intense shadow, and often coupled two by two, which appear in various parts of the planet, specially, near the terminator, and are wont to last a few days." E. S. H.

OBSERVATIONS OF SMALL SPOTS ON *JUPITER*.

Observing *Jupiter* on the morning of April 27th of this year, some rather singular black spots were seen just within the north edge of the north equatorial band. These were exactly like shadows of satellites, for which they were at first mistaken.

I recorded, "the two small spots are inky black, and seem very slightly elliptical." The seeing was excellent. Three of these peculiar spots were visible near transit when the great Red Spot was central, and, later, a fourth made its appearance at the following limb. The preceding one of the three first seen was considerably smaller than the others, and the observations refer to the two conspicuous ones,—*i. e.*, the second and third of April 27.

I have numbered these small spots 1, 2, 3, etc., in the order of increasing longitude, beginning with the preceding one of the two near the Red Spot.

Transits of the Small Dark Red Spots.

	1st Spot.	2d Spot.	3d Spot
	h. m.	h. m.	h. m.
1890, April 26......	15 53.2	16 34.2	......
" July 8......	......	11 20.3	......
" " 13......	......	......	11 55.5
" " 15......	......	12 13.0	13 37.3
" " 30......	......	9 29.8	10 48.6
" Aug. 1......	10 17.8	11 03.2	.....

Following are transits of two more of these small spots:

d. h. m.
1890, July, 14 12 30.4;
Aug., 2 9 42.9.

The above are in Mt. Hamilton mean time. Each of these small spots is now situated on a thin reddish spur that juts out from the north edge of the equatorial belt, and runs eastward parallel to it for some 25,000 or 30,000 miles. They are gaining on the Red Spot $10^s.02$ at each rotation of the planet.

In appearance the small black spots were not unlike the remarkable black spots that broke out just north of the north equatorial belt in 1880. (*See Publ.* A. S. P. No. 5, page 100, and page 111, spot *f*.)

E. E. B.

Mt. Hamilton, July, 1890.

White Spots on the Terminator of *Mars*.

The interesting phenomenon of bright spots projecting beyond the terminator of *Mars*, and presenting much the same appearance as the summits of lunar mountains and craters when first visible outside the terminator of the moon, was well seen with the thirty-six-inch refractor on the nights of July 5th and 6th. The attention of the astronomers was directed to the aspect of *Mars* on July 5th at 10^h P. s. t., by a visitor, who happened to be looking in the telescope at that time, on one of the public nights of the observatory. A sketch made by J. E. K. at this time shows a narrow elliptical white spot, from $1''.5$ to $2''.0$ long, projecting downward (northward) at a small angle with the line of the terminator. The seeing was 5, or the best which is known at the observatory. At 10^h 30^m the spot was within the disc, but still visible as an oval white patch on a darker background. This aspect is also shown in a sketch.

On July 6th the same appearance was more carefully observed by E. S. H., J. M. S. and J. E. K. A projecting spot was seen by E. S. H. at $8^h\ 3^m$ P. s. t. At $8^h\ 45^m$ it curved upward and nearly met another smaller projecting spot some 2″ farther toward the south. J. M. S. considered that there was an actual connection, although it was very faint.

The lower spot, although it changed considerably in shape, remained visible for more than an hour, and was observed to be always situated on the end of a long bright strip of the surface of the planet which lies north of *Deuteronilus*. The simplest interpretation of the phenomenon is therefore that this strip is (or was at the time of observation) elevated above the general surface. At about $10^h\ 25^m$ of July 6 the aspect was much the same as that of the spot seen on the preceding night and was no doubt produced by the same part of the planet.

Sketches were made at different times by all the observers. The principal "canals" of SCHIAPARELLI was seen as broad diffuse bands, usually very faint, but one, the *Gihon*, was remarkably strong.

It is a fact of some interest that both satellites of *Mars* were seen on one of the public nights (June 14) by a visitor, a lady, who was unaware of their existence, and that their positions were correctly indicated by her in a sketch. The planet was in the centre of the field, and not hidden behind a bar. Many other visitors saw the satellites when their positions had been pointed out.

E. S. H., J. M. S., J. E. K.

PHOTOGRAPHS OF *VENUS* AND OF *MERCURY* IN DAYLIGHT.

On July 21, a negative was made of *Venus* in full daylight with the great telescope, at $3^h\ 30^m$ P. M., with the planet one hour west of the meridian. The plate was Seed 26, the aperture eight inches, $\frac{a}{f} = \frac{1}{71}$, and the exposure $0^s.13$. There is a very strong contrast between the limb and the sky, which would have been even stronger if we had used a slower plate, a smaller aperture, and a quicker time. On August 11, similar negatives were made of *Mercury* with apertures of eight and six inches (the latter the best).

E. S. H. AND W. W. C.

PHOTOGRAPHS OF *ALPHA LYRÆ* IN BROAD DAYLIGHT.

A series of pictures of *Alpha Lyræ* was taken on August 18 with the great telescope about 5 P. M. with apertures of 33, 15, 8, 4 inches,

and with a constant exposure of $0^s.13$. The images are quite dense, so that good paper prints can be made from them. Such results have a theoretical importance in their bearing on the general problem of photographing small contrasts—as in photography of the Corona, for example. It will be of value also to be able to photograph the moon or one of the inferior planets during a close approach to a fixed star, either day or night, which can now be done under favorable conditions.

The first photographs of stars were made by the two BONDS, at the Harvard College Observatory in the years 1850–60. At first an exposure of ten seconds or more was necessary to obtain an impression of *Alpha Lyræ* on a dark sky! With our present plates it is difficult to get an exposure quick enough for such a picture.

To appreciate the amazing delicacy of sensitive plates, let any one look at the intensely bright sky at noon and reflect that modern plates are competent to register the extremely small contrast between the light of a star and the luminous background of the daylight sky on which it is projected. E. S. H. AND W. W. C.

APPOINTMENT OF MR. LEUSCHNER IN THE UNIVERSITY OF CALIFORNIA.

Mr. A. O. LEUSCHNER has been appointed to be Instructor of Mathematics in the University of California, and will take up his new duties about September 15, 1890. E. S. H.

ABSORPTION OF THE PHOTOGRAPHIC RAYS OF LIGHT IN THE EARTH'S ATMOSPHERE [BY DR. J. SCHEINER, ASTROPHYSIKALISCHES OBSERVATORIUM, POTSDAM].

This subject has been spoken of in various places (among others, in the *Publ.* A. S. P., vol. I, pp. 51, 63, 64, 114, 121). Observations to determine the absorption have been made at Harvard College Observatory, at Potsdam and at Mount Hamilton. No results have yet been published, and therefore the following paragraphs from an important article by Dr. SCHEINER in the *Astronomische Nachrichten*, No. 2969, will be of interest. Dr. SCHEINER says:

"It is to be expected that the effect of atmospheric extinction of light upon measures of photographic magnitudes will be very nearly the same as the same effect upon a ray of that particular wave-length which has the maximum photographic influence upon the sensitive

plate. This maximum for bromide-of-silver plates is near wave-length 434$\mu\mu$.

"In No. 2464 of the *Ast. Nach.** Dr. G. MUELLER has printed an extinction-table for different wave-lengths. This table does not extend so far as wave-length 434, but the corresponding values can be extrapolated with great accuracy."

[These values are as follows:

Photographic Atmospheric Absorption in Magnitudes for a Wave-Length 434$\mu\mu$.

ALTITUDE.	ABSORPTION.	ALTITUDE.	ABSORPTION.
15°	1.28 mags.	23°	0.66 mags.
16	1.18 "	24	0.60 "
17	1.08 "	25	0.55 "
18	1.00 "	26	0.50 "
19	0.93 "	27	0.47 "
20	0.86 "	28	0.45 "
21	0.80 "	29	0.42 "
22	0.73 "	30	0.40 "]†

"From my observations (in the *Pleiades*) of November 22, I found the increase in magnitude from 18°.6 to 29°.0 altitude to be 0.53 magnitude. The table gives exactly the same result. Although this complete agreement is naturally but accidental, yet it indicates that the assumption just made is approximately correct, and that MUELLER's extinction-table can be used with advantage until the publication of further investigations on this subject."—E. S. H.

MEDALS OF THE COMETS OF 1618 AND 1680.

Apropos of a note on the medal of the Comet of 1680 (*Publ.* A. S. P., vol. II, p. 124), Professor DUNÉR, Director of the Observatory of Upsala, in a letter recently received, calls attention to passages from two works‡ by J. H. MAEDLER, which describe a somewhat similar medal for the Comet of 1618. The medal is said by

* Not No. 2964, as printed in the *Ast. Nach.* 2969.

† The paragraph in brackets was obligingly communicated by Dr. SCHEINER in a private letter.

‡ These works are a translation of Dr. J. R. HIND's book on *Comets* (p. 116) and MAEDLER's *Astronomische Briefe*. Neither of these is in the Lick Observatory Library.

MAEDLER to have been struck by a Danish King, who must have been, according to Professor DUNÉR, King CHRISTIAN IV, the same who drove TYCHO BRAHE out of Uraniburg.

On the obverse, this medal displayed "a crowd of persons prostrate on the earth, and above them a terrible comet," and the reverse contained the following inscription:

> "GOTT GIB, DASS UNS DIESER KOMET-STERN
> BESSERUNG UNSERS LEBENS LERN! 1618."

or, set over into English, *God grant that this comet may teach us to amend our lives.*

Perhaps some of the correspondents of the A. S. P. can refer to a published engraving of this medal.

Professor R. WOLF, Director of the Observatory of Zurich, kindly refers me to his *Astronomische Mittheilungen*, No. 68, in which he has described a medal of the 1680 comet, which was presented by him to the Observatory of Zurich in 1887. E. S. H.

THE *SOUTHERN CROSS*—AND THE REPUBLIC OF BRAZIL.

The coins of the new Republic of Brazil bear (on the reverse) the effigy of the five chief stars of the constellation *Crux*, surrounded by the twenty-one stars which symbolize the separate provinces of the Republic.

The adoption of an astronomical symbol by the new confederacy is, perhaps, worthy of this passing note in an astronomical journal. E. S. H.

ON A BLACK TRANSIT OF THE IV SATELLITE OF *JUPITER*, OBSERVED ON AUGUST 13, 1890, WITH THE TWELVE-INCH EQUATORIAL OF THE LICK OBSERVATORY.

On the night of August 13th, while observing *Jupiter*, I saw what at first I took to be the shadow of one of the satellites on the disc. Referring to the Nautical Almanac, I found that it must be the IV Satellite in one of its black transits. Careful observations were made of it throughout the remainder of its transit. With all powers up to 500 on the twelve-inch it was perfectly black and round. No markings of any kind were seen on its disc. It was some distance preceding two of the singular small black spots that have appeared on the north edge of the equatorial belt, and was as near as possible at the same latitude. The surface of *Jupiter* rotating faster

than the apparent motion of the satellite, caused the small black spots to overtake it, and the preceding of the two was seen to catch up with and pass behind the satellite, and finally to emerge on the preceding side of it. The spot really passed very slightly north of the satellite's center and a very faint fringe of it was seen projecting slightly to the north at their conjunction, giving to that part of the satellite the effect of a penumbra, IV being much blacker than the spot.

When about three-quarters across the disc, IV appeared to have a slight brownish tinge—reddish-black—but later, this slight tinge of red disappeared and the satellite remained of a cold black color. The most singular phenomenon was presented when nearing emergence. It became smaller as it approached the limb, and seemed extended slightly north and south. It did not appear to lose in blackness so much as it did in size. Finally, while it, as a very small black speck, seemed not yet in contact with the limb, a small portion of its disc was seen protruding beyond the edge of the planet, and, when nearly half off, this portion did not appear round, but was wedge-shaped. As the satellite emerged, that part remaining on continued black, while the portion off the disc was as bright as the adjacent part of the planet. It seemed to leave the dark part behind, as it were, which, being crowded into a smaller and smaller space on the disc of the satellite, as it emerged, finally disappeared from smallness rather than from any loss of its blackness. When at last the satellite was free from the disc of *Jupiter*, it appeared extremely small and of a uniform pale, ashy tint—no spot or marking being visible upon it. As compared with Satellite I, which was near it and preceding, it was not over one-quarter as large as that satellite in diameter, and many times less bright.

During the latter part of the transit, except at the time of emergence, Mr. SCHAEBERLE watched the phenomenon with me. After emergence, we agreed that if the satellite were a disc as big as *Jupiter*, its albedo would be considerably less than that of *Jupiter*, though I was at first inclined (erroneously) to place it a little brighter than the planet. A small spot of light on a dark background is apt to appear brighter than a large surface, which is really brighter than the small spot, a fact that in estimations of this class is too important to neglect. Matched with the belt on which it appeared so inky black, it seemed to be of about the same brightness. The satellite appeared to lack luster, when compared with the surface of *Jupiter*.

During the transit I measured the distance of the centre of the satellite from the north and south limbs of *Jupiter*, the wires being

parallel with the north edge of the equatorial belt. The following are the measures in local sidereal time:

$19^h\ 49^m\ 11^s$ center of satellite from north limb $= 18''.2$ (3)
19 54 49 center of satellite from south limb $= 28''.4$ (3)

An attempt was made to measure its diameter during transit, but the seeing became too poor for the necessary high power to be used. The wires were, however, placed alongside the satellite and then separated until, by careful estimation, their centers were separated by the apparent diameter of the satellite, the resulting value being, at sidereal $20^h\ 10^m.6$, $= 2''.0$, which is to receive but very little weight.

By a careful estimation with the micrometer wire bisecting the satellite, and perpendicular to the belts, IV transited the apparent central meridian of *Jupiter's* disc at $9^h\ 42^m.2$ Mt. Hamilton mean time. Comparing this with the time derived from the entrance on to and departure from the disc, as given in the American Ephemeris, the satellite was between 14^m and 15^m ahead of its predicted time, this being verified by the observations at emergence.

When near the middle of its transit, Mr. SCHAEBERLE and myself, after a careful examination, agreed that the satellite was absolutely black and round.

The observations of this black transit, made under more favorable circumstances than any I have seen, fully convince me of the fallacy of the theory that they are due to "the sudden formation of vast areas of non-reflective surface on the satellite." The cause must be sought, not in dark spots or surfaces on the satellite, but in some peculiar influence that exists only during the time of transit—perhaps some peculiar phenomenon of light itself, as was suggested to me some years ago as a possible explanation. After observing this transit, in connection with what I have seen, both in the case of IV and III, and witnessing the phenomena there presented, I would not subscribe for one moment to the theory of spots or local changes on the face of the satellite—the explanation must be sought elsewhere. However, I must not be understood to say that there are not dark spots on the satellites—for, in June of last year, on several fine nights, with 700 on the twelve-inch, I distinctly saw irregular dark spots on III.

The importance of these dark transits requires that any notes pertaining to them should be published. I therefore append, nearly in full, my notes of this transit of August 13. The times are local sidereal time:

$19^h\ 25^m$. The satellite is round and black as ink. With powers 500, 240, 175, 150, it is perfectly black, round and sharply defined. It is larger and blacker than the small dark spots following it.

$19^h\ 56^m$. Still inky black.

$20^h\ 24^m$. IV coincides with the first black spot, and is still very black.

$20^h\ 32^m$. Still black.

$20^h\ 34^m$. It does not now appear so black; it is hazy and brownish, poor seeing. Shadow of IV on, at the following limb, and is as black as ink, but no blacker than IV was at transit.

$20^h\ 40^m$. IV is reddish brown, while its shadow is inky black.

$20^h\ 50^m$. Not quite so black as its shadow, yet it is black. It is three-quarters as large as its shadow.

$21^h\ 6^m$. Still black, but not quite so black as its shadow nor so large.

$21^h\ 10^m$. Still very dark, or black. I do not now notice any brown color; it is simply a less decided black than its shadow. This with power 175.

$21^h\ 13^m$. With 150 it is scarcely less black than its shadow, but not over two-thirds as large.

$21^h\ 17^m$. Nearing limb; still black.

$21^h\ 24^m$. Black yet, and small.

$21^h\ 29^m$. Still very dark and one-half as large as its shadow; much darker than the spot following it.

$21^h\ 30^m$. It appears bright on its preceding side; still dark.

$21^h\ 31^m$. Considerably fainter and smaller; not yet in contact.

$21^h\ 32^m$. Still dark, paler and quite small.

$21^h\ 33^m$. Very small and faintish; not yet in contact; about one-fifth as big as its shadow.

$21^h\ 34^m$. Now fainter and a little smaller than the black spot following it; not yet in contact.

$21^h\ 35^m$. Very small, faint speck.

$21^h\ 35\frac{1}{2}^m$. Part is protruding. This is as bright as the limb. The remaining portion within the limb is dark. It is one-half off.

$21^h\ 36\frac{1}{2}^m$. Outside part brighter than the limb; inside portion darker.

$21^h\ 38^m$. Protruding part is wedge-shaped. It is as bright as the limb; that portion on disc not visible.

$21^h\ 40^m$. Not yet off.

$21^h\ 42^m$. Quite small; just in contact, and brighter than adjacent belt.

$22^h 35^m$. IV is about one-half the diameter of Satellite I in size, and about one-half as bright as that satellite. It is still ashy in color, and is apparently a little brighter than the reddish equatorial belt on which it appeared so black.

While these observations were going on, a telephone message was received at the Observatory, from Mr. C. B. Hill, at the Chabot Observatory, kindly calling attention to the phenomenon. E. E. B.

MT. HAMILTON, August 15, 1890.

SOME PHOTOGRAPHIC EXPERIMENTS WITH THE GREAT TELESCOPE.

A plate was exposed, on August 4, on the multiple star *Epsilon Lyræ* which is composed of the two pairs *4 Lyræ* (magnitudes 4.6 and 6.3, distance 3″.1) and *5 Lyræ* (mags. 4.9 and 5.2, distance 2″.4) with the full aperture, and with exposures of $0^s.13$, 1^s, 2^s, 4^s, 8^s and 16^s. *Alpha Lyræ* (first magnitude) was similarly exposed on the same plate (Seed 26). Four other stars show also; namely,

w,	D M. 38°,	3229,	magnitude	7.3
x,	D M. 39°,	3505,	"	6.5
y,	D M. 38°,	3237,	"	7.8
z,	D M. 39°,	3514,	"	8.5

Some of the results from this plate may have more than a special interest, as they will show what is to be expected (and what is *not* to be expected)* from a photographic lens with the unusual relation of aperture (33 inches) to focus (570.2 inches) of 1 to 17. In such a lens 1″ of arc is about 0.0028 inches, and two stars at a distance of 3″, or even less, should show on a plate which has had the proper exposure. In fact the 1^s exposure gives very good and perfectly well-measurable images of all the stars down to magnitude 7. The probable error of a measure of the distance of the close doubles *4* and *5 Lyræ* is not above 0″.02 or 0″.03.

The diameters of the star discs are — approximately only — for

a star of	4.6	mag.,	exposed	1^s,	diameter	= 1″.3
"	4.9	"	"	1	"	= 1 .9
"	5.2	"	"	1	"	= 1 .2
"	6.3	"	"	1	"	= 1 .1
"	6.5	"	"	1	"	= 0 .7
"	7.3	"	"	1	"	= 1 .3
"	7.8	"	"	4	"	= 1 .5
"	8.5	"	"	8	"	= 1 .2
"	8.5	"	"	16	"	= 1 .5
"	8.5	"	"	4	is just measurable for position.	

* "Jedes Fernrohr hat seinen Himmel."

It is evident from these figures that the stars are not all of the same color.

In the earlier reports on the Paris photographic telescope ($a = 13$ inches, $f = 13$ feet) it was stated that an exposure of 60^s gave all the stars of the D M. (magnitudes 1–9.5). Since the very sensitive American plates have been introduced, it is probable that even less exposure is required. In the last report of the Potsdam Observatory, it is said that in 15 seconds, stars of the 9.5 magnitude are "*angedeutet*," which I understand to mean are just plainly visible, but probably not easily measurable.

From what precedes, it is clear that double-stars which are fairly bright, whose components are at the same time fairly equal in magnitude, and whose distance is not less than 2″ or 3″, can be quickly photographed and easily and accurately measured, provided the scale of the plate is known. Ten or twelve exposures can be made in five minutes, after the telescope is once pointed. The accidental error of a single measure is small. The constant error cannot be large. The subsequent measures on the plate can be very readily made with the extremely convenient measuring-engine of the Observatory. It would seem, then, that there is a whole class of double stars which is suitable for photographic observation with our long-focused telescope. The very close stars and the very unequal stars must always be observed visually.

The Parallax of Nebulæ.

If in photographing a nebula, like that in *Lyra* or STRUVE 6, for example, we give a long exposure, the result is a picture of the object which resembles the visual image very closely. If the original exposure is halved, the nebula covers a smaller area. If the exposure is halved again, the nebula becomes still smaller. By suitably diminishing the exposure-time the nebula may be made to appear very much like a ninth or tenth magnitude star, and in such a case it is perfectly easy to make measures of its position which are very accurate—as accurate as those on stars.

It appears, from actual experiment, that by adopting the very simple device of suitably reducing the exposure-time, a nebula may be made to give an image upon which perfectly precise measures of position can be made. I see no reason why a series of such negatives, all made with exactly the same exposure-times, continued throughout a year, should not be suitable for the determination of the parallax. E. S. H.

The Chromatic Aberration of the Pulkowa Thirty-Inch Refractor.

Since the paper on the "Chromatic Aberration of the Thirty-six-inch Equatorial of the Lick Observatory" was printed in No. 9 of these *Publications* (p. 160), a volume printed by the Pulkowa Observatory has been received.* It contains, among many other matters of interest, a description of the optical constants of the thirty-inch equatorial, by Dr. Hermann Struve. The chromatic aberration of the objective was investigated by the spectroscopic method, and all colors between the lines D and b were found to have very nearly the same focus. For other parts of the spectrum the following results were obtained:

Line.	*Distance from D.*
C	3.0mm.
F	6.4
$H\gamma$	32.9

From these observations the color curve of the objective can be drawn, although, as they give only four points on the curve, it is not possible to do so with entire accuracy. The curve appears to be quite similar to the curves of the Vienna and Mt. Hamilton equatorials, but shows a slight advantage of the Pulkowa refractor over these instruments, in regard to color correction. In the following table the chromatic aberrations of the three telescopes are compared, but since so few points are given on the curve for the Pulkowa refractor, no attempt has been made to extend the table to the values of λ given on page 164, *Publications* No. 9. The quantities entering in the table there given have been reduced to the units adopted by Struve.

Line.	Vienna Telescope.		Pulkowa Telescope.		Lick Telescope.	
	df	$\frac{h}{f}$	df	$\frac{h}{f}$	df	$\frac{h}{f}$
	mm.		mm.		mm.	
C	2.7	.0000170	3.0	.0000115	5.3	.0000162
D	0.0	.0000000	0.0	.0000000	0.0	.0000000
F	6.0	.0000378	6.4	.0000245	11.4	.0000349
$H\gamma$	23.5	.0001478	32.9	.0001258	48.3	.0001471

In this table df is the difference in millimetres between the focal length for the stated line and the focal length for the D line; $\frac{h}{f}$ is

* *Zum 50-jährigen Bestehn der Nicolai-Hauptsternwarte.* St. Petersburg, 1889.

the diameter of the circle in which the cone of rays from the object-glass intersects the focal plane for the *D* line, expressed in terms of the mean focal length. In the table on p. 164 the radius of this circle is given.

The color curves for these telescopes show a remarkable similarity when compared with the curves given by VOGEL* for a number of telescopes of older construction. This is no doubt due partly to the greater uniformity in the quality of optical glass as now manufactured, and partly to the more uniform practice of modern opticians. The rapid rise of the color curve at the upper end of the spectrum, corresponding to a great diameter of the circles of chromatic aberration for short wave-lengths, is considered rather advantageous than otherwise for visual observation, since a diffuse and dim background of false color is less offensive than a narrow but bright border around telescopic images.

J. E. K.

SIMPLE METHOD FOR POINTING A PHOTOGRAPHIC TELESCOPE UPON A GUIDING-STAR DURING A LONG EXPOSURE.

In Dr. von KONKOLY'S *Praktische Anleitung zur Himmelsphotographie* (1887), pages 287, 288, 289, 290 are devoted to descriptions of different devices for the purpose named above.

A very simple and effective method, invented independently by Mr. SCHAEBERLE and Mr. BARNARD at the Lick Observatory, is to use a finder with a dark field in which two wires are disposed at right angles to each other, thus:

The wires must be heavy enough to be visible against a dark sky. The guiding-star is brought to the intersection of the wires and thrown out of focus. The circle formed by the star-disc thus diluted can be readily kept symmetrically bisected by the cross.

J. M. S. AND E. E. B.

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* *Monatsberichte der Akademie der Wissenschaften zu Berlin*, April, 1880.

The Solar Corona.

In the July number of *Himmel und Erde*, Dr. Koerber, in a review of the magnetic and mechanical theories of the Solar Corona, seems to imply that what one theory lacks the other supplies.

In advance of the regular publication of my memoir on the "Mechanical Theory," I only wish to say here, that the exceptional phenomena which the magnetic theory apparently fails to account for are the strongest proofs of the mechanical theory, while the phenomenon of the *polar rays*, the strongest point in favor of the magnetic theory, is shown to be a necessary consequence of the perspective over-lapping and interlacing of the equatorial streamers projected at the poles. The position and varying inclination of the theoretical rays (which do not, as a rule, coincide with the streamers) are shown to coincide with the observed positions of the rays, thus doing away with the necessity of introducing forces of a magnetic character to account for certain phenomena. J. M. S.

Gift of an Electric-Lighting Plant to the Lick Observatory by the Edison General Electric Company, of Orange, New Jersey.

The Lick Observatory has seriously felt the want of an electric-lighting plant to provide illumination for the circles of the great telescope, etc., etc. For some time past we have been in correspondence with the Edison General Electric Company (through A. E. Kennelly, Esq.) looking to supplying this lack. A plan for the outfit had been prepared and was under consideration when, on August 5th, we received a letter from Mr. Kennelly to say that the Edison Company had decided to offer to the Lick Observatory the complete plant of steam-engine and boiler, dynamo, belting, main wire, controlling wire, and a set of storage-cells in duplicate, the whole as a free gift. The Regents of the University of California gratefully accepted this unexpected and generous present at their meeting of September 4th.

And the astronomical staff of the Observatory desire to add their cordial recognition of this most valuable addition to the equipment of the institution. If there were any known way of presenting the freedom of the Observatory in a box to Mr. Edison and to his co-adjutors, it would be instantly adopted. As it is, the grateful thanks of the Observatory are returned to them for their thoughtful and timely gift to science. E. S. H.

Minutes of the Meeting of the Board of Directors, held at the Lick Observatory, September 13, 1890.

A quorum was present. The minutes of the last meeting were read and approved.

The following members were duly elected:

T. W. Backhouse, F. R. A. S.,	West Hendon House, Sunderland, England.
Miss E. Brown, ...	Further Barton, Cirencester, Birmingham, England.
J. Rayner Edmands, . . .	Harvard College Observatory, Cambridge, Mass.
W. C. Fitzsimmons, ...	Care of J. H. Fountain & Co., Riverside, Cal.
Louis Gex, ...	Rua Conde Irajá, No. 20, Rio de Janeiro, Brazil.
Geo. N. Hitchcock, ...	San Diego, Cal.
A. E. Kennelly, ...	Edison Laboratory, Orange, New Jersey.
Dr. L. L. Leggett, ...	Masonic Temple, Cleveland, Ohio.
Hon. E. B. Mastick, . . .	Office of the Lick Trust, San Francisco, Cal.
G. W. Nicolls, ...	Banco Nacional, Rio de Janeiro, Brazil.
Professor H. B. Perkins, . .	University of Southern California, Los Angeles, Cal.
William Maxwell Read, . .	Harvard College Observatory, Cambridge, Mass.
William Thaw, Jr., ...	Pittsburgh, Penn.

Henry Phipps, Jr., was duly elected a life member, to date from July 12.

The following resolutions were adopted:

Whereas, Mrs. R. A. Proctor was, at the last meeting of this Board, proposed as a member of this Society through misapprehension and elected,

Resolved, That, at her request, the said election be canceled.

It was further

Resolved, That, at his request, the election of Hon. A. King take effect January 1, 1891.

The Treasurer delivered to the Board his official bond, duly executed, and three bank-books, as follows: German Savings and Loan Society, No. 64,347, and S. F. Savings Union, Nos. 50,715 and 51,529. The Board instructed the President to take charge of these books and of the bond. (They are deposited, with other A. S. P. papers and property, in the safe of the Director of the Lick Observatory at Mt. Hamilton.)

Mr. Pierson reported that rooms for the Society had been secured in the seventh story of the new building of the California Academy of Sciences, on Market street, San Francisco.

Adjourned.

Minutes of the Meeting of the Astronomical Society of the Pacific, held at the Lick Observatory, September 13, 1890.

The minutes of the last meeting were read and approved.

The Secretary read a list of the presents received since the last meeting, and the thanks of the Society were voted to the givers.

The list of new members elected was read by the Secretary.

The President called the attention of the members to the following circular issued by the Committee on the Memorial to Father PERRY:

"'FATHER PERRY' MEMORIAL.

"At a meeting recently held under the presidency of Sir EDWARD WATKIN, Bart, M. P., it was judged that a memorial to the late Father PERRY, F. R. S., would be sure to command general approbation and support.

"Father PERRY'S labours in solar physics and terrestrial magnetism, his ever ready willingness to lecture to the people, his cheerful acceptance of the most onerous posts in many astronomical expeditions, culminating in the sacrifice of his life at the observation of the eclipse of the 22d December, 1889, are well known to all.

"It has been decided that the best mode of perpetuating his name would be to aid the carrying-on of the astronomical work in the observatory in which he so long laboured.

"It is well known that had any testimonial been offered to Father PERRY during his lifetime he would have devoted it to this purpose. To use his own words in a lecture at the Royal Institution, in May, 1889, shortly before his death: 'For the last ten years I have been anxiously endeavouring to make Stonyhurst as efficient an observatory as the means at my disposal would admit.'

"Astronomical work at Stonyhurst has long been hampered by the insufficiency of light supplied by the present 8-inch object-glass for the equatorial telescope. It is proposed, therefore, either to erect a new telescope (which is much needed) with a 15-inch object-glass, or to furnish the present equatorial stand with a 15-inch objective. It would require £2700 for the complete telescope and house, while £700 would suffice for the objective alone. It is hoped, however, to raise the more magnificent monument to his memory. Whichever be adopted, the telescope and the house in which it stands will bear the name of the 'Father PERRY' Memorial; and the work done with it will be published under this name. Memorials of a like nature have been erected on other occasions.

"Those who have not already subscribed to this fund, and are desirous of doing so, are invited to send a donation either to the 'Father PERRY' Memorial Account, at the London Joint Stock Bank, Limited, Pall Mall Branch, London, S. W.; or to ARTHUR CHILTON THOMAS,

Hon. Secretary and Treasurer, pro tem.

Marldon Chambers, 30 North John Street, Liverpool.

COMMITTEE:

"Lord ARUNDELL of Wardour.
"Sir ROBERT S. BALL, LL.D., F.R.S., Royal Astronomer for Ireland.
"J. BILLINGTON BOOTH, Esq.
"W. H. M. CHRISTIE, Esq., M.A., F.R.S., Astronomer Royal.
"Lord CLIFFORD.
"The Rev. REGINALD COLLEY, S.J., Rector of Stonyhurst.
"A. A. COMMON, Esq., F.R.S.
"RALPH COPELAND, Esq., Ph.D., Royal Astronomer for Scotland.
"Prof. EDWARD S. HOLDEN, LL.D., Director of the Lick Observatory, U.S.A.
"Mons. J. JANSSEN, Membre de l'Institut, Directeur de l'Observatoire de Meudon, France.
"Prof. J. NORMAN LOCKYER, F.R.S.
"JOSEPH J. PERRY, Esq.
"LEWIS H. PERRY, Esq.
"ISAAC ROBERTS, Esq., F.R.S.
"Prof. ARTHUR SCHUSTER, Ph.D., F.R.S.
"Sir GEORGE GABRIEL STOKES, Bart., M.P., M.A., D.C.L., LL.D., President of the Royal Society.
"E. J. STONE, Esq., M.A., F.R.S., Director of the Radcliffe Observatory, Oxford.
"HENRY STOURTON, Esq., President of the Stonyhurst Association.
"H. H. TURNER, Esq., M.A., B.Sc., F.R.A.S., Royal Observatory, Greenwich.
"E. GRANVILLE WARD, Esq.
"Prof. C. A. YOUNG, Ph D, Director of the Princeton Observatory, New Jersey, U.S.A.
"ARTHUR CHILTON THOMAS, Esq., Hon. Secretary and Treasurer, pro tem."

A short sketch of the life and labors of Father PERRY was given by Mr. HOLDEN, who stated that he would gladly take charge of any contributions to this memorial, and duly forward them to the Hon. Treasurer in England; and that at the proper time a list of such contributions would be printed in the *Publications* A. S. P.

Glass copies of enlargements of the moon, of the crater *Copernicus*, of the planet *Jupiter*, were exhibited to the meeting, as well as a glass copy of the Cluster in *Hercules*. All these were made with the great telescope.

The following papers were presented:

a. Prof. L. WEINEK: "On Drawings of the Moon."

b. Prof. MILTON UPDEGRAFF: "Some Notes on Astronomy in South America."

c. A. O. LEUSCHNER: "Corrections to Oppolzer's Bahnbestimmung."

d. R. SCHMIDT: "A Suggestion of a Way to Forward our Knowledge of the Asteroids."

e. A. O. LEUSCHNER: "Elements of Comet Coggia (July 19)."

f. A. O. LEUSCHNER: "Elements of Comet Denning (July 23)."

g. Prof. DANIEL KIRKWOOD: "The Age of Periodic Comets."

h. E. E. BARNARD: "On the Photographs of the Milky Way, taken at the Lick Observatory in 1889."

i. J. E. KEELER: "On the Motions of the Planetary Nebulæ in the Line of Sight."

Owing to lack of time, only (*g*) and (*i*) were read. The first eight papers are printed in the present number of the *Publications*. The paper of Mr. KEELER will be printed in No. 11, and extra copies of it have already been distributed.

The Society then adjourned, to meet in San Francisco, November 29, 1890.

OFFICERS OF THE SOCIETY.

EDWARD S. HOLDEN (Lick Observatory),	*President*
WM. M. PIERSON (508 California Street, S. F.),	*Vice-Presidents*
FRANK SOULE (Students' Observatory, Berkeley),	
J. H. WYTHE (Oakland),	
CHAS. BURCKHALTER (Chabot Observatory, Oakland),	*Secretaries*
J. M. SCHAEBERLE (Lick Observatory),	
E. J. MOLERA (850 Van Ness Avenue, S. F.),	*Treasurer*

Board of Directors—Messrs. ALVORD, BURCKHALTER, GRANT, HILL, HOLDEN, MOLERA, PIERSON, SCHAEBERLE, SOULE, WYTHE, ZIEL.

Finance Committee—Messrs. PIERSON, MOLERA, HILL.

Committee on Publication—Messrs. HOLDEN, KEELER, YALE.

Library Committee—Messrs. MOLERA, BURCKHALTER, PIERSON.

Committee on the Comet Medal—Messrs. HOLDEN (*ex-officio*), SCHAEBERLE, BURCKHALTER.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year.

It is intended that each member of the Society shall receive a copy of each one of the Publications for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title page and index of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied to members, so far as the stock in hand is sufficient, on the payment of one dollar to either of the Secretaries.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," at the rooms of the Society, 408 California Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

Vol. II. San Francisco, California, November 29, 1890. No. 11.

ON THE MOTIONS OF THE PLANETARY NEBULÆ IN THE LINE OF SIGHT.

By James E. Keeler.

The following paper contains a preliminary account of researches on the spectra of the planetary nebulæ, and a statement of the results of measurements which show that some of the nebulæ, which have hitherto been supposed to be at rest relatively to the solar system, have a considerable motion in the line of sight.

The first spectroscopic observations of nebulæ made at the Lick Observatory were undertaken at the request of Dr. Huggins, who asked that the position of the brightest line in the spectrum of the *Orion* nebula should be determined with reference to the lower edge of the magnesium fluting which falls at nearly the same place, with the aid of the thirty-six-inch equatorial, and also that the character of the nebular lines should be examined. The origin of the nebular lines was at that time the subject of considerable discussion.

Although the nebula was too far past the meridian when Dr. Huggins' letter was received to allow of the satisfactory employment of the comparison apparatus for determining positions, an examination of the lines was made, under sufficiently favorable circumstances, with a number of different spectroscopes. The largest of these, with which were made the observations hereafter to be described, has a collimator of twenty inches focus and an observing telescope of about half that length. A single 60° prism was first employed, then a compound prism of about three and one-half times the dispersion of the latter, and finally a Rowland grating of 14,438 lines to the inch. With all these different degrees of dispersion, and also with the other spectroscopes employed, the nebular lines appeared to be perfect monochromatic images of the slit, widening when the slit was widened, and narrowing to exces-

sively fine, sharp lines when it was closed up. The brightest line showed no tendency to assume the aspect of a "remnant of fluting" under any circumstances of observation, but had always the appearance characteristic of light emitted by a gas at low temperature and pressure.

A few measures which were made of the position of the brightest line, under extremely disadvantageous circumstances, were unsatisfactory, and probably erroneous, and they are not given in the accompanying list, but will be repeated at the first opportunity. This part of the observations being undecisive, I therefore, at Dr. HUGGINS' request, examined the spectra of the nebulæ *G. C. 4234* (Σ 5) and *G. C. 4373*. In both of these nebulæ the brightest line fell well above the lower edge of the MgO fluting, with which it could not be made to coincide by any mal-adjustment of the comparison-spark; but while thus amply confirming the opinion of Dr. HUGGINS in regard to the non-coincidence of the nebular line and the terminal line of the magnesium fluting, the difference in position of the brightest line in the two nebulæ was so considerable, and so much greater than the errors of observation, as to show conclusively that one or both of the nebulæ had a considerable motion in the line of sight. I therefore undertook the determination of the position of the bright lines in the spectra of all the nebulæ within the range of the apparatus, with the greatest attainable degree of accuracy. Some of these measures have already been completed, and the results are given in the present paper.

The positions of the three brightest lines in the spectra of a number of planetary nebulæ were determined in 1868 by Lieutenant HERSCHEL,* but with apparatus so deficient in optical power that the whole range of the small displacements I have observed was covered by the errors of observation. Similar measures were made by BREDICHIN † in 1875, but the accuracy attained was not much greater than that of the observations just quoted. Professor BREDICHIN concluded, however, that the lines in the different nebulæ are identical in origin. VOGEL,‡ in 1871, determined the position of the brightest line in the spectra of six nebulæ (including the nebula of *Orion*) with a degree of precision much greater than that of previous observations, but still not sufficient

* *Royal Soc. Proc.*, vol 16, p. 451.

† Spectre des Nebuleuses. *Annales de l'Observatoire de Moscou*, ii (2me liv.) p. 60.

‡ *Bothkamp Beobachtungen*, Leipzig, 1872.

for the purpose now under consideration. In a paper published in 1874, HUGGINS* gives the results of an examination of seven gaseous nebulæ, including the nebula of *Orion*, and states that in no instance was any change of relative position of the nebular line and the lead line (used in comparison) detected. From observations made at Greenwich in 1884, MAUNDER concluded that the nebula of *Orion* has little, if any, motion in the line of sight.

As the statement of HUGGINS in the paper just referred to cannot be reconciled with my own observations, I at first attributed the differences in position of the nebular lines to constant errors affecting my own apparatus; but the most varied tests failed to reveal the existence of such errors, and only convinced me of the reliability of the results. As the displacements are small, and the nebular lines faint, it is probable that the observations are beyond the range of all but the most powerful apparatus.

The conclusion that the nebulæ have no motion relatively to the solar system would appear on *a priori* grounds to be improbable. The stars, which in general are found to have considerable motions in space, are, according to modern views, evolved from pre-existing nebulæ by a process of contraction or condensation, and any motion of translation possessed by the star must have been inherent in the original nebulæ, since in no way could such a motion have been acquired by any internal action during the process of condensation. The *absence* of motion in the nebulæ would, in fact, if proved by observation, be a remarkable circumstance which would need to be explained.

The large star spectroscope which was used in the observations at the Lick Observatory is one of the finest specimens of BRASHEAR'S work. A complete description of the instrument will not be given here, but certain features, which are directly concerned in the measurements, require notice. The collimator is of twenty inches focal length, the observing telescope ten and one-half inches, and both objectives are of Jena glass. The effective aperture of the collimator, when used on the thirty-six-inch equatorial, is 1.06 inches, and the actual aperture was reduced to this by a stop, in order to limit the emergent beam from the comparison-spark. Two eye-pieces were used, one giving a power of 7.3 and the other of 13.3 diameters. The higher power was generally found to be the more satisfactory, except on unusually faint nebulæ. The micrometer has a fine

* *Royal Soc. Proc.*, vol. 22, p. 253.

wire, a coarse wire, and a pointer. The value of one revolution is 3′ 10″.8.

Light from the comparison-spark or tube is thrown into the collimator by a totally-reflecting prism, and the arrangement which I have devised for the Lick Observatory spectroscope is intended to be free from the objections which have been made to the usual construction in which the comparison-prism is employed. An image of the spark, intentionally somewhat out of focus, is formed on the slit by a lens having a greater angular aperture than the collimator objective. The comparison-prism can be moved smoothly along the slit in the direction of the spark by turning a milled head within reach of the observer. The slit is variable in length as well as in breadth, two small slides moving lengthwise equally from the center, and operated by a knob, being the means by which the change is effected. A diagonal eye-piece, which is slightly withdrawn when the adjustment of the spectroscope is complete, is used for viewing the slit from behind.

When an object, such as a planetary nebula, is observed, it is first centered in the slit by the slow motions of the telescope, with the aid of the diagonal eye-piece just mentioned. The slit is then shortened until its length is just equal to the diameter of the nebula, and its width is reduced to suit the requirements of observation. The slit is then evidently completely filled with light from the nebula. After its image has been bisected with the micrometer wire, the comparison-prism is moved into place, and the image of the nebula is replaced by the image of the comparison-spark. It is evident that the rays of light from both sources enter the same part of the slit, traverse the same path in the spectroscope, and fall upon the same part of the micrometer wire. If desired, the two spectra can be compared directly, the comparison-prism being then moved so as not to completely cover the open part of the slit.

In observing the nebulæ, a Rowland grating of 14,438 lines to the inch was used, and the measures were made in either the third or fourth spectrum, the telescopes being set at an angle of 40°. The third spectrum was considerably the brighter, but experiment showed that the error of an observation expressed in wave-lengths was usually less in the fourth spectrum. With a wave-length of 5005 in the fourth spectrum, in the center of the field, one revolution of the micrometer = 2.21 tenth-metres, the dispersion being equal to that of about twenty-four prisms of 60°.

In the third spectrum, at the same place, one revolution = 3.71 tenth-metres.

With this dispersion, the brightest nebular line only was in the field. The lower of the two nitrogen lines and the edge of the magnesium fluting at λ 5006 were separated by a considerable interval, a small fraction of which could be measured by the micrometer. The nebular line was, of course, faint, but by narrowing the slit until the line was of the same width as the coarse micrometer wire (about 0.4 tenth-metres), the line could be occulted by the wire and the settings made with much accuracy.

The position of the nebular line was determined with reference to both the lower edge of the magnesium-flame band and the lead line at λ 5004.5 (adopting the wave-length given by Dr. HUGGINS), the two independent measurements serving as a mutual check. The lead line, however, furnished a much better mark for the micrometer. As an example, I give a summary of the measures in the spectrum of the nebula Σ 6. The telescope was usually directed to this nebula before beginning work on others, in order to verify the adjustment of the spectroscope. In the table, a positive sign means that the nebular line was of greater wave-length than the line of comparison; the negative sign, that it was of smaller wave-length.

Measures in the Spectrum of Σ 6.

DATE.	DISTANCE FROM LEAD LINE.		DISTANCE FROM MGO FLUTING.		OBSERVED WAVE-LENGTH.	CORRECTION FOR EARTH'S MOTION.	CORRECTED WAVE-LENGTH.
1890.	Microm. Rev.	Tenth-metres.	Microm. Rev.	Tenth-metres.			
July 10	+0.64	+1.41	−0.18	−0.40	5005.94	−0.13	5005.81
" 17	+0.63	+1.39	−0.23	−0.51	5005.87	−0.17	5005.70
" 24	....	....	−0.12	−0.29	5006.07	−0.21	5005.86
" 25	....	....	−0.15	−0.33	5006.03	−0.21	5005.82
" 25	....	....	−0.13	−0.29	5006.07	−0.21	5005.86
" 31	+0.69	+1.52	−0.14	−0.31	5006.05	−0.25	5005.80
Aug. 1	....	....	−0.15	−0.33	5006.03	−0.26	5005.77
" 7	....	....	−0.13	−0.29	5006.07	−0.28	5005.79
" 8	....	....	−0.10	−0.22	5006.14	−0.29	5005.85

The adjustments of the apparatus were tested as often as possible by measures of the displacement of lines in the spectra of the moon and planets. In the case of the moon (and sun) the coincidence of lines by direct comparison was always perfect. Comparisons made by the aid of the micrometer wire, in the same way as in observing nebulæ, showed a displacement so small as to be usually within the accidental error of observation; thus, five measures of the position of the D_1 line in the lunar spectrum on the evening of July 31st gave a displacement of + 1 division of the micrometer, or 0.03 tenth-metres; five measures by another observer gave the same displacement, and five by still another observer a slightly greater negative displacement. On a number of days the displacement of the D lines was measured in the spectrum of *Venus*, the third spectrum of the grating being employed. Direct comparison showed a small displacement of the lines of the planet toward the violet, which was measured with the micrometer by alternate settings on the D lines and on the sodium lines produced by impurities in the magnesium points of the comparison apparatus, according to the method employed in the observations of nebulæ. The results are exhibited in tabular form below. One revolution of the micrometer for this position of the grating equals 3.29 tenth-metres, equivalent to a motion of 104.3 miles per second in the line of sight.

Measures of the Motion of Venus in the Line of Sight.

Date.	Observer.	Displacement of D lines.	Observed Motion.	Computed Motion.	C – O.
		r.	miles.	miles.	miles
Aug. 16	K	– 0.070	– 7.3	– 8.1	– 0.8
" 22	K	– 0.085	– 8.9	– 8.2	– 0.7
" 22	C	– 0.072	– 7.5	– 8.2	– 0.7
" 30	K	– 0.070	– 7.3	– 8.3	– 1.0
Sept. 3	K	– 0.0793	– 8.3	– 8.3	0.0
" 4	K	– 0.079	– 8.2	– 8.3	– 0.1

The smallness of the accidental errors of observation is shown in the above table by the agreement of the individual results, and the absence of constant errors by the agreement of the mean with the actual value of the quantity measured.

Occasional observations of nebulæ were made with a smaller

spectroscope, having a single 60° prism and ten-inch telescopes. This instrument gives brighter spectra than the large one with the same dispersion, but it has no micrometer or other measuring apparatus. It is referred to in the observations as spectroscope *B*.

I give, finally, the individual results for the nebulæ so far examined. The descriptive notes accompanying the record of observations on the appearance of nebulæ are my own, taken from my note-book used at the telescope. In general, they agree with the descriptions of others, although they contain some facts not hitherto published. Little attention was, however, paid to the ordinary visual observations, which were made either with the diagonal eye-piece of the large spectroscope, the slit being opened wide, to allow the object to be seen, or with an ordinary negative eye-piece on nights when the small spectroscope was used.

In the measures, the distance in tenth-metres of the nebular line from the lead line at λ 5004.5 is, for brevity, indicated by *L*, and its distance from the edge of the MgO fluting, just below, by *M*. The distance $M-L$ was found by several series of independent measures to be 1.86 tenth-metres. It was somewhat greater when the brilliant light from burning magnesium was used, as the illumination of the terminal line is not equal on both sides; but with the relatively feeble light of the comparison-spark used in the observations, the distance was that given above. Referred to the same scale as the lead line, the wave-length of the MgO fluting is therefore λ 5006.36.* As the distance $M-L$ is indirectly measured, through the nebular line, at each complete observation of a nebula, the agreement of the individual results with the value 1.86 tenth-metres gives a check on the accuracy of the observations. It may be noted that, in general, the observations of a nebula were made without any recollection of the results obtained on previous nights, and that the spectroscope was frequently dismounted during the period covered by the observations. Each complete determination of the position of a nebular line consists of five measures of its distance from the lead line and five from the magnesium fluting, the entire operation consuming more time than might be supposed by one unfamiliar with the difficulties of managing the necessarily complicated apparatus employed in such work.

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* The scale is ANGSTRÖM'S, known to require a correction of about one part in about eight thousand; but we are here concerned with relative positions only. Professor ROWLAND has kindly communicated to me the wave-length of the lead line from one of his photographs. It is 5005.6 $\pm$ 0.1.

Observations of Nebulæ.

(The places are for 1890.)

G. C. 4058. R. A. = $15^h\ 3^m\ 28^s$, $\delta = +56°\ 11'$.

This spindle-shaped nebula is divided lengthwise by a narrow, perfectly dark, straight rift, on each side of which, near the n. p. end, is a minute star of about the sixteenth magnitude. The continuous spectrum was examined for carbon bands with spectroscope *B*, but it was excessively faint, and no details could be seen. The light seemed to end rather abruptly at the lower end of the spectrum, in the orange. A short-focus telescope would be better for this object.

G. C. 4234. (Σ 5.) R. A. = $16^h\ 39^m\ 53^s$, $\delta = +24°\ 0'$.

This nebula was first examined on May 15. It is nearly round, and has a bright stellar nucleus, giving a continuous spectrum, in which a bright line at D_3 was suspected on one occasion. Outside of the nebula, but connected with it by a faint band of light, is a condensation of nebulosity, the spectrum of which is gaseous.

The following measures have been made:

Date.	L.	M.	Observed λ.	Reduc. to Sun.	λ.
June 13	....	−0.72	5005.64	−0.10	5005.54
" 27	....	−0.77	5005.59	−0.18	5005.41
" 27	....	−0.82	5005.54	−0.18	5005.36
July 3	+0.99	−0.75	5005.55	−0.20	5005.35
" 4	+1.02	....	5005.52	−0.21	5005.31
" 10	+1.02	....	5005.52	−0.24	5005.28

The second set of measures on June 27 was made in the third spectrum.

G. C. 5851. R. A. = $17^h\ 7^m\ 53^s$, $\delta = -12°\ 47'$.

The following measures were made in the third spectrum, and are all that have been obtained so far. The brightest line was very faint in the large spectroscope:

Date.	L.	M.	Observed λ.	Reduc. to Sun.	λ.
Aug. 15	+1.00	....	5005.50	−0.44	5005.06

G. C. 4355. R. A. = $17^h\ 55^m\ 43^s$, $\delta = -23° \ 2'$.

The spectrum of this (trifid) nebula is continuous, but short, being confined to the green and blue, and there is a brightening near the middle of it, the wave-length of which could not be estimated with spectroscope *B*. The brightest star involved gave a spectrum without lines, although if there had been dark lines as strong as they usually are in class I, they could probably have been seen.

G. C. 4361. R. A. = $17^h\ 56^m\ 56^s$, $\delta = -24° \ 23'$.

The lines were much too faint for observation with the large spectroscope. Examined with spectroscope *B* on August 21, three bright lines were seen, which were probably the usual nebular lines, although the two lowest seemed to be very close. The nebula is full of knots or condensations, having the same spectrum as its more diffuse portions, and many bright stars are involved in it, in the spectra of which no lines could be detected. This nebula is too diffuse for a long-focus telescope.

G. C. 4373. R. A = $17^h\ 58^m\ 35^s$, $\delta = +66° \ 38'$.

The appearance of this nebula in the thirty-six-inch equatorial has been described by Professor HOLDEN and Professor SCHAEBERLE.* The lowest nebular line falls higher in the spectrum than in any nebula yet examined, being nearly in coincidence with the lead line. Measures were obtained as follows:

DATE.	L.	M.	OBSERVED λ.	REDUC. TO SUN.	λ.
July 4	+0.29	-1.55	5004.80	0.00	5004.80
" 10	+0.29	-1.66	5004.75	0.00	5004.75
" 25	+0.55	-1.13	5005.14	0.00	5005.14
Aug. 15	+0.35	-1.55	5004.83	0.00	5004.83
" 22	+0.33	-1.55	5004.82	0.00	5004.82

The measures of July 25 were unsatisfactory, as a violent wind was shaking the telescope. They are, however, given with the others.

* *Mon. Not. R. A. S.*, vol. 48 (1888), p. 388.

On July 19 the spectrum of the nucleus was examined with spectroscope B, but nothing remarkable could be seen. Although there were indications of bright knots on the continuous spectrum below the group of lines in the green, they were not sufficiently distinct for a trustworthy estimate of their positions. VOGEL'S "*Spuren von Lichtlinien bei 527, 518, 509, 579*," were looked for, but were not visible, and D_3 could not be seen.

N. G. C. 6537. R. A. $= 17^h\ 58^m\ 42^s$, $\delta = -19°\ 51'$.

The brightest line was too faint for observation with the large spectroscope.

G. C. 4390. (Σ 6.) R. A. $= 18^h\ 6^m\ 45^s$, $\delta = +6°\ 50'$.

The measures of the position of the brightest line, have been given already. They make the wave-length of the line corrected for the motion of the earth, λ 5005.81.

This is one of the brightest nebulæ that I have examined. The third nebular line in the third spectrum was sufficiently bright for comparison with the $H\beta$ line of a hydrogen tube, although the measures were difficult, and the nebular line was found to be 0.86 tenth-metres (or, corrected for the motion of the earth, 0.60 tenth-metres) less refrangible. This evidently agrees (in direction, if not in amount) with the low position of the brightest line, shown by the measures already given.

Viewed with an ordinary eye-piece, the nucleus of Σ 6 does not appear perfectly sharp, but seems to blend into the surrounding nebula. An examination of its spectrum with spectroscope B confirmed this view as to the connection between the nebula and its nucleus, the continuous spectrum of the latter shading off somewhat gradually into that of the nebula, and showing a great increase in brilliancy where it was crossed by the nebular lines. Besides the usual lines 5005, 4957, $H\beta$ and $H\gamma$, several others were seen in the spectrum of the nucleus. D_3 was quite bright, and was identified by comparison with the sodium line from a spirit-lamp. $H\alpha$ was seen with great difficulty, at the extreme lower end of the spectrum. Other faint bright lines appeared at about 5680, 5400 and 4450, the positions being mere eye-estimates, and dark bands were suspected at two or three places between the brightest line and D_3. The principal lines were fine and sharp in the spectrum of the nebula, but fuzzy and considerably broadened in that of the nucleus. These observations are evidently in harmony

with the natural supposition that the nucleus is composed of condensed nebulous matter at a higher temperature and pressure.

G. C. 4447. R. A. = $18^h\ 49^m\ 30^s$, $\delta = +32^\circ\ 54'$.

The brightest line in the spectrum of the Ring nebula in *Lyra* was much too faint for measurement with the grating. No observations have been made with the small spectroscope.

N. G. C. 6790 (= D. M. + 1°.3979). R. A. = $19^h\ 17^m\ 20^s$, $\delta = +1^\circ\ 18'$.

This is one of the very small stellar planetary nebulæ discovered by Professor PICKERING. It is rated in the D. M. as 9.4 mag.; is round, bright, and has a very minute nucleus, the general appearance of the nebula being much like that of Σ6, on a smaller scale.

In this nebula the brightest line falls lower in the spectrum than in any nebula yet examined, being *less* refrangible than the edge of the magnesium fluting. This fact was seen at once from a direct comparison, and is also shown by the measures.

DATE.	L.	M.	OBSERVED λ.	REDUC. TO SUN.	λ.
July 31	+2.30	+0.46	5006.81	−0.14	5006.67
Aug. 1	+2.45	+0.44	5006.88	−0.15	5006.73
" 8	+2.51	....	5007.01	−0.29	5006.72

G. C. 4510. R. A. = $19^h\ 37^m\ 46^s$, $\delta = -14^\circ\ 25'$.

The intrinsic brilliancy of this large nebula is small, and the measures were difficult. Those of August 8 were made in the third spectrum, and as the slit was wider than usual, the comparisons with the lead line are much more reliable than those with the magnesium fluting.

DATE.	L.	M.	OBSERVED λ.	REDUC. TO SUN.	λ.
July 17	+1.33	−0.91	5005.64	−0.02	5005.62
Aug. 8	+1.37	−0.48	5005.87	−0.19	5005.68

G. C. 4514. R. A. = $19^h\ 41^m\ 51^s$, $\delta = +50^\circ\ 16'$.

The large, round, fairly bright disc of this nebula is apparently without structure. The nucleus is very bright, and was examined with

spectroscope B, in the expectation of finding a complicated bright-line spectrum. The spectrum was, however, continuous, and although bright points could be glimpsed in it, their positions could not be determined. In the large spectroscope the nebular lines were quite dim.

The following measures have been obtained:

DATE.	L.	M.	OBSERVED λ.	REDUC. TO SUN.	λ.
July 25	+1.54	−0.55	5005.92	−0.02	5005.90
Aug. 15	+1.39	−0.57	5005.84	0.00	5005.84

G. C. 4532. R. A. = $19^h\ 54^m\ 51^s$, $\delta = +22°\ 25'$.

The lines of the Dumb-bell nebula were too faint for observation with a grating. No observations have been made with spectroscope B.

G. C. 4628. R. A. = $20^h\ 58^m\ 11^s$, $\delta = -11°\ 48'$.

This is a large, round nebula, with a bright inner ring, considerably elongated E. and W., and a very small nucleus. The following measures were obtained with the large spectroscope. Those of July 31 were rather difficult, on account of the bright moonlight on the floor around the observer.

DATE.	L.	M.	OBSERVED λ.	REDUC. TO SUN.	λ.
July 31	+0.66	−1.13	5005.20	+0.04	5005.24
Aug. 22	+0.71	−0.88	5005.35	−0.13	5005.20

N. G. C. 7027 (=D. M. +41°.4004). R. A. = $21^h\ 2^m\ 55^s$, $\delta = +41°\ 48'$.

This is the brightest nebula that I have yet examined, and its spectrum is exceedingly interesting. The nebula is irregular in outline, and contains two central condensations, one of which has an oval and fairly well-defined outline. The other is much fainter and more diffuse. On the following side is a small star, just at the border of the nebula. The spectrum was examined on August 21 with spectroscope B. The lowest line is ***brilliant***, the second also very bright, but the hydrogen lines are relatively dim, and an attempt to compare the third line with $H\beta$, with the large spectroscope, failed. By widening the slit, a monochromatic image of the central conden-

sation could be seen in the brightest line, which became a mere knot or brightening on the line when the slit was narrowed. The continuous spectrum of the nebula showed but a comparatively slight brightening at the nucleus, which is evidently in a much less condensed state than the nuclei of Σ 6 and many other nebulæ of its kind. Several bright lines below the strong group in the blue were visible only in the spectrum of the central condensation, probably on account of their faintness. One of these, the lowest visible, was in the estimated position of D_3; another, very well seen, was at about λ 5400, and between this and the brightest line were several others, of which the only one that could be definitely fixed was at about λ 5200. It should be remembered that these positions are from mere eye-estimates, using the intervals between known lines as terms of comparison. This nebula also shows the line at λ 4700 ±, which is visible in the spectrum of *G. C. 4964.*

With the large spectroscope, measures of the position of the brightest line were obtained, as follows:

DATE.	L.	M.	OBSERVED λ.	REDUC. TO SUN.	λ.
Aug. 15	+1.57	−0.35	5006.04	+0.07	5006.11
" 22	+1.55	−0.20	5006.11	+0.03	5006.14

G. C. 4964. R. A. = $23^h\ 30^m\ 27^s$, $\delta = +41°\ 56'$.

This nebula is annular, with a bright inner ring and a very small nucleus. It is somewhat elongated N. and S.

The spectrum shows, in addition to the two brightest nebular lines and the hydrogen lines $H\beta$ and $H\gamma$, a line at about λ 4700, which was seen by HUGGINS in his first spectroscopic observations of nebulæ, in 1864. Examined with spectroscope *B*, on August 21, no other lines than the above were seen. The lines showed bright knots where the inner ring of the nebula was crossed by the slit. The spectrum of the nucleus was excessively faint, but there was a broad, faint, continuous spectrum, due to the nebula itself.

The following are measures with the large spectroscope:

DATE.	L.	M.	OBSERVED λ.	REDUC. TO SUN.	λ.
Aug. 1	+1.19	−0.95	5005.50	+0.32	5005.82
" 7	+0.80	−1.04	5005.31	+0.30	5005.61

In seeking to determine the motions of the nebulæ from these observations a difficulty presents itself which does not occur in observations of the motions of stars in the line of sight. The origin of the brightest nebular line is unknown, and hence we have no terrestrial substance with which to make a direct comparison. If, however, we had a large number of determinations of the position of the nebular line, from observations of nebulæ distributed with some uniformity throughout the sky, we could regard the mean position as that due to a nebula without motion, and the residuals obtained by comparing the individual results with the mean would represent the corresponding displacement of the line for each nebula. This has been done with the observations so far obtained; but as the nebulæ observed are far from having the regular distribution which is desirable, and are few in number, the numerical results are not to be regarded as final. Observations of other nebulæ will be made here until a sufficient number shall have been obtained.

Motions of Planetary Nebulæ in the Line of Sight.

(A positive sign signifies recession; a negative sign, approach.)

Nebula.	λ.	Displacement.	Motion per Second.
	tenth-metres.	*tenth-metres.*	*miles.*
G. C. 4234 (Σ 5)	5005.38	− 0.30	− 11.2
G. C. 5851	5005.50	− 0.18	− 6.7
G. C. 4373	5004.85	− 0.83	− 31.0
G. C. 4390 (Σ 6)	5005.81	+ 0.13	+ 4.8
N. G. C. 6790	5006.71	+ 1.03	+ 38.4
G. C. 4510	5005.65	− 0.03	− 1.1
G. C. 4514	5005.87	+ 0.19	+ 7.1
G. C. 4628	5005.22	− 0.46	− 17.2
N. G. C. 7027	5006.13	+ 0.45	+ 16.8
G. C. 4964	5005.72	+ 0.04	+ 1.5
Mean............	5005.68		

It is probable that a greater number of nebulæ would give a somewhat smaller mean wave-length for the position of the brightest line, and that therefore the motions of approach in the above table are too large, and those of recession too small. The single comparison

of the third line in the spectrum of Σ 6 with the hydrogen line $H\beta$ also indicates a higher mean position of the nebular line, although the observation was subject to rather large accidental errors. The *difference* of motion of the nebulæ given in the table I believe to have a considerable degree of accuracy,—*i. e.*, that the errors do not much exceed two or three English miles.

The spectra of the nuclei of planetary nebulæ have a remarkable resemblance to the spectra of the WOLF-RAYET and other bright-line stars, and intimate connection between these objects, if established by further observations, would place the bright-line stars first in the order of development. The D_3 line appears in the central condensation of a number of bright nebulæ, and, with sufficient light, would probably be seen in many of them, and this line is also prominent in most of the bright-line stars. Other lines in the nebulæ and stars are probably of identical origin. At my request, Mr. BURNHAM and Mr. BARNARD examined the WOLF-RAYET stars in *Cygnus* for traces of surrounding nebulosity, but with only negative results.

In making the observations described in this paper I was very kindly assisted by Mr. W. W. CAMPBELL, of the Detroit Observatory, University of Michigan, and Mr. A. O. LEUSCHNER, of the University of California, and these gentlemen also verified many of the observations. Without their aid, the work would have been much more laborious, and the results more incomplete.

LICK OBSERVATORY, September 4, 1890.

NOTE.—Since the above was printed, I have seen No. 293 of the *Proceedings of the Royal Society*, in which Mr. LOCKYER describes his recent observations, and arrives at conclusions which cannot be reconciled with my own. There is, however, nothing that I could wish to change in my paper, since it is simply a record of observed facts. In only one place (observations of Σ 6) have I referred the observed appearances to a cosmical theory, and the reader can easily supply any other explanation that is in accordance with the facts.

The errors which Mr. LOCKYER mentions as liable to arise from imperfect adjustment of the collimator axis and from parallax, seem to me excessive, if the telescopes are good and the adjustments are carefully made, and if they existed they would make observations of motion in the line of sight impossible. Certainly no errors approaching them in magnitude were produced in my own apparatus, when, in testing for constant errors, the various adjustments were purposely disturbed by amounts greater than could occur in practice. Among the many ex-

periments which were made was the one suggested by Mr. LOCKYER—rotating the spectroscope 180° between measures, but no appreciable effect was produced upon the position of the nebular line.

As regards accuracy of positions, there is a great advantage in using a very high dispersion, such as was employed in these measures, since any angular displacement of the parts of the apparatus produces but a small error measured in wave-lengths. The measures are also *differential*, the reference line being in the same field and the telescope fixed in position. They are affected by any error in the assumed place of the reference line, but this is immaterial for the purposes of the investigation.

On referring to my measures, it will be seen that they apparently have a vastly higher degree of accuracy than that which Mr. LOCKYER considers attainable. When it is remembered that these measures were made on different nights (the spectroscope usually having been dismounted in the interval), and frequently without any recollection of the results previously obtained, it appears in the highest degree improbable that the agreement of the different results for the same object should be the result of accident. In the observations of the motion of *Venus* in the line of sight, the interval between the *D* lines appeared under an angle of 1° 17′, as viewed with the eye-piece, and any good observer, on noting the small displacement of the lines of the planet, would admit the possibility of measuring this displacement to within a tenth part of its value. Hence, the accuracy of the measures in this case cannot be regarded as accidental, and for the nebulæ, on which even a higher dispersion was employed, the probable error of a setting was not much greater.

In regard to the *character* of the chief nebular line, I can only repeat that I see no tendency in it to assume the fluted appearance described by Mr. LOCKYER, either in the nebula of *Orion* or in the others I have observed, some of which are fainter and some very much brighter. Near the nucleus of a nebula, if it has one, the lines become broader and hazy, but equally so on both sides, and, as nearly as their different degrees of brightness will allow one to judge, all the lines are affected alike.

For faint, extended nebulæ, the great focal length of the thirty-six-inch equatorial is a positive disadvantage, and I do not attach much weight to the negative results obtained in the examination of some of these objects giving continuous spectra.

J. E. K.

ON THE WAVE-LENGTH OF THE SECOND LINE IN THE SPECTRA OF THE NEBULÆ.

By James E. Keeler.

In testing the results published in a paper* on the motions of the planetary nebulæ in the line of sight, I made a few measurements which give, incidentally, the wave-length of the second nebular line. Although the method employed (that of angular measurement with a graduated circle) was not the most favorable for entire accuracy, the high dispersion which was used gives the results a degree of precision which is, at least, equal to that attained by previous observers, and it therefore seems worth while to give a short account of the observations.

The object of the observations was to ascertain whether (as was altogether probable) the second nebular line was equally displaced with the first in the spectra of those nebulæ for which such differences of position were detected, or whether the differences of position were confined to the brightest line alone, a possible, though highly improbable, alternative. For this purpose two bright nebulæ were chosen, in the spectra of which the difference of position of the brightest line was nearly the greatest observed, and the distance between the first and second lines was measured in each. The arrangement of the apparatus was the same as in the observations described in my former paper, and it is only necessary to say, in addition to the description there given, that the observing telescope is provided with a twelve-inch circle divided on the edge, on silver, to 10′, and read by two opposite verniers to 10″. A small electric lamp, in a lantern on the lower end of the observing telescope, throws light on the ground-glass shade of one of the reading microscopes, and also illuminates the wires of the micrometer. The color of the light which enters the micrometer-box can be varied to approximately match any part of the spectrum, by means of a revolving disc carrying colored glasses. Only one vernier is ordinarily read, the eccentricity being very small. Means are provided for making every adjustment that the observer could wish, and I have to thank Mr. Brashear for various useful additions to the original design of the instrument.

* Page 265 of the present number.

In making the measures, the micrometer-head was first set to about $2^r.60$. The coarse wire was then in the center of the field, and the reading on the slit, when the telescope was brought into line with the collimator, was very nearly 0°. The circle was then set to 140°, making the angle between the axes of the telescopes about 40°, and the grating turned until the brightest nebular line in the fourth spectrum fell upon the coarse micrometer wire. The telescope was directed alternately upon the first and second nebular lines by turning the tangent screw, the circle being read for each setting, until as many measures were obtained as was desirable. The illumination, controlled by a switch in the hand of the observer, was used only in bringing the micrometer wire approximately on the nebular line, the final setting being made by occulting the line in a dark field. The reflected image of the slit from the surface of the grating was then observed, and finally the slit itself, the grating being removed (or turned edgewise). These observations give all the data for computing, by the formulæ for the diffraction grating, the wave-length of the brightest line and the difference of wave-length of the first and second lines, the absolute wave-length to be regarded as merely approximate and only useful as a check.

The formula for the reflecting grating is:

$$n\lambda = d\,(\sin\psi - \sin\phi)$$

in which ϕ = angle between the normal to the grating and the incident ray.

ψ = angle between the normal to the grating and the diffracted ray (ϕ and ψ being measured in opposite directions from the normal).

λ = wave-length.

n = order of spectrum.

d = distance between centres of lines of the grating.

For two rays measured in same position of the grating,

$$n\,(\lambda_1 - \lambda_2) = d\,(\sin\psi_1 - \sin\psi_2).$$

The nebulæ selected were *G. C. 4373* in *Draco* and *N. G. C. 7027* in *Cygnus*, for which the positions of the brightest line, corrected for the earth's motion, are respectively λ 5004.85 and λ 5006.13. Observations of *G. C. 4373* on the night of September 19th, gave the following data:

	° ′ ″
Circle reading on brightest nebular line, . . .	140 1 40
Distance between first and second lines, from ten measures, $= \Delta\psi$	1 8 23 ± 6″
Circle reading on reflection of slit, ...	214 32 30
Circle reading on slit, ...	0 1 10

$n = 4$.

Hence, $\psi_1 = 57° \; 15' \; 10''$, $\psi_2 = 56° \; 6' \; 47''$, $\phi = -17° \; 15' \; 40''$.

For this grating, $d = \frac{1}{14438}$ in. $= 17592.1$ tenth-metres.

Substituting in the formulæ, $\lambda_1 = 5004.1$, which is sufficiently near o the true value, and $\lambda_1 - \lambda_2 = \Delta\lambda = 48.05$ tenth-metres.

The only instrumental constant liable to change during the course of the observations, on account of flexure, etc., is the direction of the normal to the grating; but the distance between the nebular lines is very little affected by a small change in the position of the grating, as may be seen by differentiating the expression for $\Delta\psi$ with respect to ϕ. A change of 2′ in ϕ produces a change of only 6″ in $\Delta\psi$.

The following table exhibits the results of four different series of measurements, which are all of about the same weight:

DATE.	NEBULA.	$\Delta\psi$	$\Delta\lambda$
		° ′ ″	*tenth-metres.*
Sept. 3	*N. G. C.* 7027	1 8 25	48.07
Sept. 19	*N. G. C.* 7027	1 8 2	47.82
Sept. 18	*G. C.* 4373	1 8 10	47.92
Sept. 19	*G. C.* 4373	1 8 23	48.05
Mean			47.96

From these observations, the mean of the measured distances between the nebular lines is, for *N. G. C. 7027*, 1° 8′ 14″, and for *G. C. 4373*, 1° 8′ 17″; but the difference of position of the lower line for the two nebulæ is, from the table on page 278, 1.28 tenth-metres, or about 1′ 50″ in angular measure, the motion of the earth having very little effect at the time of observation on either nebula, and this is so much greater than the error of measurement that it is safe to conclude that the second line in both nebulæ is equally displaced with the first line, and that in both nebulæ the lines have the

same origin. Considering the small differences in the above table to be due to errors of observation, we have 47.96 tenth-metres for the difference of position of the two lines; hence the wave-length of the second line is

for *N. G. C. 7027*..........4958.2 tenth-metres
for *G. C. 4373*...........4956.9 "

or for the mean of the ten nebulæ on page 278, 4957.7 tenth-metres.

The values obtained by other observers are as follows:

HUGGINS.......	λ 4957.0
D'ARREST......	4956.6
COPELAND......	4958.0

THE MOTION OF *ARCTURUS* IN THE LINE OF SIGHT.

BY JAMES E. KEELER.

While the spectroscopic observations of nebulæ described on page 265 *et seq.* were in progress, a few measures of the displacement of the *D* lines in the spectrum of *Arcturus* were made, and these measures, when corrected for the orbital motion of the earth, gave a motion of the star toward the solar system of only four English miles per second. In view of the fact that observations of the planets with the same apparatus gave results closely in accordance with theory (see, for example, the table on page 270), it appeared to be probable that the large motion of over fifty miles per second, hitherto accepted for this star, was erroneous, although the discrepancy led to a careful examination of all possible sources of error in our own apparatus. Without entering into the details of the various experiments which were made, it may be stated that no other evidence could be found for the existence of constant errors than the discordance between the measured motion of *Arcturus* and that which has been commonly accepted.

In No. 2896 of the *Astronomische Nachrichten*, Professor H. C. VOGEL gives the motions of a number of stars in the line of sight, determined by a photographic method with a much higher degree of precision than that of any previous measurements. *Arcturus* was not included in the list, but measures of the motion of this star have been kindly supplied by Professor VOGEL, with permission to publish

the results. It will be seen that their agreement with the Mt. Hamilton measures is extremely satisfactory. The unit adopted by Professor VOGEL—the German geographical mile—has been changed into English statute miles in the following table:

α *Bootis.* POTSDAM.

Date.	Observed Motion.	Earth's Motion.	Motion of Star Referred to Sun.
	miles.	*miles.*	*miles.*
1888, Oct. 5...	−3.3	+2.3	−5.6
1889, April 4...	−6.5	−2.3	−4.2
" April 30...	−0.3	+4.6	−4.9
" May 17...	+4.7	+8.7	−4.0
1890, April 15...	−3.2	+0.6	−3.8
" May 23...	+6.2	+9.8	−3.6
Mean..............................			−4.4 ± 0.2

The observations made at the Lick Observatory are as follows:

α *Bootis.* MT. HAMILTON.

Date.	Observed Motion.	Earth's Motion.	Motion of Star Referred to Sun.
	miles.	*miles.*	*miles.*
1890, April 10...	− 4.6	0.0	−4.6
" Aug. 7...	+10.4	+14.4	−4.0
" Aug. 15...	+ 9.3	+13.5	−4.2
Mean..............................			−4.3

The observations are not sufficiently numerous for a reliable estimate of the probable error, and they are of very different weights, the measures of August 15th being much the best.

THE ASPECT OF *JUPITER* IN 1889.*

By James E. Keeler.

The opposition of *Jupiter* in 1889 was a very unfavorable one for observation, the planet being at nearly its greatest possible southern declination. Nevertheless, as the conditions at most of the American and European observatories were even more unfavorable than at Mt. Hamilton, I examined *Jupiter* at Professor Holden's request, as often as circumstances would permit, and made drawings whenever the atmospheric conditions were sufficiently good. Usually a power of 320 was employed on the thirty-six-inch equatorial, and occasionally higher powers. On a few nights the twelve-inch telescope was used, and sometimes the six-and-a-half-inch telescope, in order to compare the appearance of the planet as shown by it with that presented by the larger instruments. As would naturally be expected the advantage of the thirty-six-inch equatorial was most marked on nights of fine definition, although on *all* occasions the larger telescope showed its superiority. Seen with the latter instrument on a fine night, the disc of *Jupiter* was a most beautiful object, covered with a wealth of detail which could not possibly be accurately represented in a drawing. Under these circumstances scarcely any portion of *Jupiter*, except the red spot and the extreme polar regions, was of a uniform tint, the surface being mottled with flocculent and more or less irregular cloud masses.

The main object of the observations was to record the aspect of the surface of *Jupiter*, showing all the details that could be perceived with the telescope and transferred to paper in the limited time allowed by the rotation of the planet. For accurately fixing the longitudes of the different markings and their times of rotation, observations of transits over the central meridian are more suitable, as in such work the attention can be concentrated on a single object. In making the drawings special attention was paid to the markings which seemed to be characteristic of the appearance of *Jupiter* at the opposition of that year.

Each drawing occupied from fifteen to twenty minutes. The work could not be continued after the expiration of that time, on

* The drawings of *Jupiter* given in this number were printed in the August and September numbers (for 1890) of the journal *Himmel und Erde*, published by the *Gesellschaft Urania*, in Berlin, and the present article is abridged from the accompanying German text.

account of the changes caused by rotation of the planet. All positions and dimensions are mere eye-estimates, but a few micrometer measurements made toward the end of the observations show that the estimates are fairly accurate. The errors of drawing have not been corrected in preparing the plates, which are faithful copies of the original records. Twenty-four drawings were made during the opposition, and of these, eight were selected for reproduction by lithography.

Description of the Principal Features of the Surface of Jupiter.

The equatorial zone, occupying the space between the red belts, was marked in the center of a salmon-colored stripe, which was occasionally interrupted by an extension of the white clouds on the sides of the zone. The edges were brilliant white, and were formed of rounded cloud-like masses, which at certain places extended into the red belts as long streamers. These streamers formed the most remarkable and curious feature of the equatorial regions. They are the cause of the double or triple aspect which the red belts present in small telecopes, and of which Dr. TERBY has given a description and drawing in *A. N.*, No. 2928. In this connection I may state that it did not require the thirty-six-inch equatorial to show this structure of the red belts, as Dr. TERBY seems to infer in a paper presented to the Belgian Academy of Sciences, for it could be seen, although imperfectly, with the six-and-a-half inch telescope, and with the twelve-inch telescope the streamers I have referred to were shown very distinctly. The thirty-six-inch telescope, which, being the most powerful instrument at my command, was naturally used in making these observations, brought vastly more difficult details into view; and if these are inadequately represented in my drawings, the fault must be ascribed to the draughtsman, and to the limited time allowed by the rotation of the planet.

Near their junction with the equatorial zone the streamers were white and definite in outline, but they became redder in tint toward their outer extremities, and more diffuse, until they were lost in the general red color of the background. When the seeing was good they were seen to be formed of irregular rounded or feathery clouds, fading toward the outer ends, until the structure could no longer be distinguished. These streamers, when long, invariably pointed toward the following limb of *Jupiter*, and from all observed appearances they were masses of cloud projected outward from the equatorial zone, and gradually left behind by the forward drift of the

equatorial regions. That there was a flow outward from the junction with the zone was determined by the motion of bright points, or knots, on the streamers. In the drawing of July 9, two such brightenings are shown on the streamer just below the red spot. On July 11, they were both somewhat farther from the root of the streamer, but the outer knot had moved farther than the inner one, so that the distance between them had increased, as shown in the drawing of this date. It was seldom, however, that spots sufficiently definite for such observations could be found.

In many cases two of these streamers were seen side by side, the outer one always having its origin nearer the preceding limb of the planet, as they never crossed. On no occasion were more than two parallel streamers seen, a third, where it met the other two, seeming to be crowded into the white outside boundary of the red belt, as in the drawings of July 10 and July 12. The portions of the equatorial zone surrounding the roots of well-marked streamers were somewhat brighter than at other places, and it is a curious circumstance that they were almost invariably suffused with a pale olive-green color, which seemed to be associated with great disturbance, and which was rarely seen elsewhere. It was not possible to indicate this in the drawings.

One part of the equatorial zone, in longitude about 228°, manifested a special degree of activity. It is shown in the drawings of July 15 and July 20. In this vicinity the changes of form seemed to be most rapid, and a few short streamers occur which bend in a direction contrary to the usual one. If we accept the explanation of the formation of streamers already given as correct, we may regard these short streamers as formed by clouds projected with a sufficient velocity to overcome for a short time the current due to the forward drift of the equatorial regions.

The red belts presented on all occasions the appearance of a passive medium, in which the phenomena of the streamers and other forms shown in the drawings were manifested. These phenomena would be exactly reproduced by streamers of cloudy white matter floating in a semi-transparent reddish fluid, sometimes submerged and sometimes rising to the surface, and it is by no means impossible that such is actually their nature. The dark spots frequently seen on the red belts usually occupied spaces left by sharp turns in the streamers, and they were of the same color as the belts, but deeper in tint, as if the fluid medium could be seen to a greater depth.

The great red spot on the southern hemisphere is shown in several of the drawings. It was of a pale pink color, slightly lighter in the middle. Its outline was a fairly true ellipse, framed in by the bright white clouds of the adjacent belt. The surrounding frame of white clouds was continuous, but it was very narrow at the south preceding end, so that when the seeing was poor the gray belt terminating at that place seemed to blend with the spot. The following end of the spot was marked by a dark shading.

In the plates the spot is shown slightly too small, an error which is due partly to the original drawings and partly to the process of reproduction. The length of the spot, as determined by a few observations of Mr. BARNARD'S, was about forty-three minutes of time, or (in projection) about 18,500 miles.

Following the red spot, the two white belts on the south faded into a broad, uniform gray belt, on which were numerous brilliant white spots, forming one of the most beautiful features of the surface of *Jupiter*. The smaller ones were round, and seemed to be bright knots on the faded ends of the belts just mentioned. Large oval spots, with smaller ones placed near them in a curiously symmetrical manner, follow in nearly the same latitude, and are shown in many of the drawings. An isolated white spot in a considerable southern latitude is shown in the drawings of July 10 and July 12.

The bright spots described above seemed to exert a repellent influence on the narrow belts in their vicinity, as may be seen by the arching away of the belts just above the spots in the drawings of July 10 and July 15, but it by no means follows that a repellant force actually exists. It was only on nights of good definition that this peculiarity could be observed.

The cloud-like appearance of the surface of *Jupiter* was most strongly marked in the series of parallel belts on the northern hemisphere. The appearance of these belts is occasionally beautifully reproduced in the sea of terrestrial clouds which sometimes pours through the valley west of Mt. Hamilton, under a clear sky and bright sun, far below the level of the observatory.

No white spots like those on the southern hemisphere were ever seen north of the equator. Dark spots occurred, but they were merely unusually dark cloud-masses in the spaces between the light belts. As in former years, the greatest activity in the internal forces of *Jupiter* was exhibited in the southern hemisphere.

ASTRONOMICAL INSTRUMENTS IN COURSE OF CONSTRUCTION IN THE UNITED STATES.

NOTE.—The Committee on Publication will be glad to receive from instrument-makers and opticians in the United States, from time to time, brief notices of important instruments and pieces of apparatus which are in course of construction. The notices should be short, and especial stress should be laid upon novelties of design or of execution. The Committee reserves the right to recommend for printing only those portions of lists furnished which seem to have particular interest to the members of the Society. Mr. BRASHEAR, under date of August 30th, kindly furnishes the following list.

E. S. H., J. E. K., C. G. Y.

Instruments and Apparatus Just Completed, and now in Course of Construction, at the Astronomical and Physical Instrument Works of J. A. BRASHEAR, *Allegheny, Pennsylvania.*

One Star Spectroscope, for Lick Observatory.

One Equatorial Mounting, with Controlled Clock. All motions brought to eye-end, etc. For the Willard Photographic Telescope of Lick Observatory. Ordered by Hon. C. F. CROCKER.

One Spectroscope, for stellar and solar work, for Carleton College Observatory. This instrument is very complete, being provided with Jena glass objectives and prism, a fine grating, and reversion apparatus for rotating the sun's image, electric illumination and comparison attachments, micrometer of the LINDSAY-GILL form, cylindrical lenses, etc.

A duplicate of the above, in anticipation of the wants of two astronomers.

One Smaller Spectroscope, for Vassar College Observatory.

Two duplicates of the above, for stock.

One Large Spectroscope and Spectrograph, for Prof. C. A. YOUNG, Halstead Observatory, Princeton, New Jersey. This instrument is to be of the highest grade, and will probably be the finest in the United States. It is to have visual and photographic objectives, gratings and a battery of large THOLLON prisms, with every accessory to do the best solar, planetary and stellar work.

One sixteen-inch Object Glass, for Carleton College Observatory.

One twelve-inch Object Glass, for Brown University Observatory.

One twelve-inch Object Glass, for Mr. G. E. HALE's Observatory, Chicago.

One six-inch Object Glass, for Mr. HENRY BERGER's Observatory, Allegheny.

One six-inch Object Glass, for Mr. CHARLES REMINGTON, Camden Astronomical Society.

One twelve-inch Reflecting Telescope, for Mr. SAMUEL MARSDEN, St. Louis.

One six-and-a-half-inch Reflecting Telescope, for Mr. F. L. SMITH, Oshkosh, Wisconsin.

One six-and-a half-inch Reflecting Telescope, for Mr. W. CULLEN, JR., Merrimac, Wisconsin.

Four Special Plane Mirrors of speculum metal and steel, for the Observatory of Paris, Prof. DESLANDRES.

Special Photometer, for Prof. S. P. LANGLEY, Smithsonian Institution.

Special Quartz and Rock-Salt Lenses, for Smithsonian Institution.

Two Large Quartz Lenses, for Prof. A. W. WRIGHT, Sloan Physical Laboratory, Yale University.

And many minor pieces.

OBSERVATIONS OF THE TRANSIT OF *JUPITER'S* SATELLITE IV. (OCTOBER 2, 1890.)

BY C. B. HILL.

The following observations were made with the eight-and-a-half-inch equatorial of Chabot Observatory, Oakland, using powers of from 90 to 400 diameters.

Sky clear, atmosphere at beginning only fair—say 3.

Commenced observation at $6^h\ 06^m$ P. S. T. (at which time by American Ephemeris, IV should be hanging on edge of planet, about at external contact), but could see no trace of satellite. Suspected "duskiness" at following edge, just north of belts.

$6^h\ 10^m$. "*Duskiness*" seen to be circular and within limb; evidently internal contact of Satellite IV.

$6^h\ 18^m$. Satellite still faint, "dusky," one diameter within, apparently commencing to darken.

$6^h\ 20^m$. Much blacker. Cannot say but what this change is owing *partially* to improved atmospheric conditions.

$6^h\ 22^m$. Satellite perfectly round, and jet black.

$6^h\ 27^m$. Satellite two diameters from limb.

$6^h\ 32^m$. Satellite three diameters from limb.

$6^h\ 39^m$. Satellite perfectly black. Atmosphere, good (nearly 4). Satellite tangent to north edge of north reddish belt, at times seems perfectly round, at other times imagine it to be flattened on side nearest limb. At this point Mr. BURCKHALTER comes up, immediately pronounces image of satellite "cut off" at point I have mentioned, and also on apparent upper outline. Atmosphere quite good at times, but I cannot see any flattening except at the north following limb.

AWARD OF THE DONOHOE COMET MEDAL.

The Comet Medal of the Astronomical Society of the Pacific has been awarded to Monsieur JÉROME COGGIA, Astronomer of the Observatory of Marseilles, for his discovery of a comet on July 18, 1890, at $10^h\ 9^m$, Greenwich mean time. This is the eighth comet discovered by M. COGGIA.

The Committee on the Comet Medal,
EDWARD S. HOLDEN,
J. M. SCHAEBERLE,
CHARLES BURCKHALTER.

NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

DARK TRANSIT OF THE III SATELLITE OF *JUPITER*.

The third satellite was observed as a dark body on the disc of *Jupiter* on the evening of Sept. 2d. The transit was nearly over before the planet could be seen, and the observations were much interrupted by clouds.

The satellite was visible on the inner edge of the north equatorial belt, partly on the belt and partly on the bright equatorial region. It was very dark—darker than the small dark spots on the north belt following. The following measures were made of its position on the disc of *Jupiter*.

Sidereal time, $17^h\ 39^m$ distance from south pole $=26''.0$ (2)
" " 17 43 " " north " $=19.7$ (2)

It was first seen at $17^h\ 25^m$. Below are the most important notes:

$17^h\ 48^m$. Still dark. It is exactly like the small dark spots in size and depth of color. (Seeing = 1.)

$17^h\ 53^m$. Still dark; perhaps a little smaller.

$17^h\ 55^m$. It is paler and smaller than the dark spots.

$17^h\ 57^m$. III is very small, but still dark.

$17^h\ 59^m$. Still dark, and very small; about one-fifth the diameter of its shadow.

$18^h\ 0^m$. A very small dark speck.

$18^h\ 2^m$. Excessively small and dark.

$18^h\ 4^m$. A very small dark speck near p. limb.

$18^h\ 6^m$. It is lost; but almost instantly the pale round disc of the satellite appeared in relief on the planet.

$18^h\ 8^m$. Looking carefully, there is a tiny dark speck at the following edge of the satellite.

$18^h\ 9^m$. The disc of III is quite white, and the dark speck has vanished. The satellite is whiter and brighter than the limb.

After the satellite had emerged from the disc of *Jupiter*, no spot could be seen on it with any power. (Seeing = 3.) It was much brighter than any portion of the planet.

The important point in observations of the phenomena of these dark transits will be to keep a close watch of the satellite at the moment of its transition from light to dark, and *vice versa*; for upon this point hinges the true explanation of the phenomenon.

The appearance at the time of this transition was the same in the case of Satellites IV (Aug. 13) and III, except that for III the change occurred some time before reaching the limb (as in all my previous observations of it).

At a certain point the dark satellite begins to diminish in size—getting smaller and apparently remaining stationary. The appearance is as if the satellite were slipping out from under some obscuring medium, which could only be seen when on the satellite, and which grows smaller and smaller as the satellite leaves it, until it is finally crowded off at the following edge. These remarks refer only to the end of the dark transit, as I have not yet had the opportunity of witnessing the beginning of such a transit at any time with the twelve-inch.

Any observations of these dark transits are very valuable; for it will be through the accumulation and discussion of such observations that this remarkable phenomenon will be explained.

Here is a good opportunity for members of the A. S. P. possessing even small telescopes to contribute something of value. They should frequently examine *Jupiter* during the transit of any of his moons, especially in transit of IV and III.

It is just as important to know that they were not dark or black during transit; and therefore all records of non-dark transits are valuable.

Of these satellites, I frequently transits as a dusky spot, but not black. II I have never seen dark, nor do I know of any observations

of it as a dark spot. III and IV transit as dark or black spots, more frequently than would be supposed.

The following were the observations of the satellite as it left the planet:

Internal contact......	7^h	19^m	21^s	Mt.	Hamilton	m. t.
One-half off..........	7	21	5	"	"	"
External contact......	7	25	55	"	"	"

According to American Ephemeris, the egress should have been at $7^h\ 26.7^m$, Mt. Hamilton m. t. E. E. B.

Mt. Hamilton, Sept. 3, 1890.

Dark Transits of *Jupiter's* First Satellite.

A dark transit of *Jupiter's* first satellite occurred on the evening of August 23d. As this was a public night at the Observatory, it was not possible to observe the phenomenon properly; but from such views as were obtained from time to time with the thirty-six-inch equatorial, the satellite, which near the limb of *Jupiter* appeared as a bright white spot, reached equality of brightness with the surface of the planet at about one-fifth of its path on the disc from the limb, and near the center of the disc appeared as a round pale, grayish spot. At egress the order of appearances was reversed.

The satellite traversed the northern half of the white equatorial zone. Its shadow, which was projected on the same belt, was perfectly black.

Almost the same phenomena were observed in the transit of the first satellite on August 30th. J. E. K.

A Possible Explanation of the Dark Transits of the Satellites of *Jupiter*.

The phenomena presented by the dark transits of *Jupiter's* satellites are among the most puzzling in the solar system, and any explanation which does not do violence to known natural laws, and is within the bounds of ordinary probability, must be regarded as entitled to some amount of consideration. It is from this standpoint that I wish to present the following as, at least, a possible explanation.

The principal facts to be accounted for are these:

1. In ordinary transits, the satellite is bright when projected upon the surface of *Jupiter* near the limb, and is usually lost sight of when it reaches the central parts of the disc.

2. Occasionally the satellite appears darker than the surface of *Jupiter* when in transit, even when projected on the brightest parts

of the disc, and the depth of shade may be very considerable, as a satellite has often been mistaken for its shadow. On leaving the disc, the satellite nevertheless appears quite bright when projected against the sky.

3. Dark transits of satellites increase in frequency with the order of distance from the primary, being more common for the outer satellites than for the inner ones.

4. The phenomena are irregular in occurrence, and therefore not predictable.

It is now generally held that the body of *Jupiter* is still intensely heated, possibly to a point approaching self-luminosity. Almost all observed facts support this view. An argument which has been made against it,—that the greatest activity of *Jupiter* is manifested in the regions which are most exposed to solar radiations,—is not entitled to any weight, since the sun itself, which does not derive its heat from external sources, exhibits the same excess of activity in the vicinity of the equator. Accepting then this view as to the constitution of *Jupiter*, there must be a considerable heat radiation from the planet, which doubtless affects, to a greater or less extent, the physical conditions of the satellites.

When a satellite is projected upon the central portion of *Jupiter's* disc, it is usually invisible. This indicates an albedo which is surprising in a small non-luminous body, and points to an unusual condition of things on its surface.

Let us now suppose what is certainly extremely probable, that the satellite is a cold, hard body with an albedo not greater than that of ordinary rock; and further, what is by no means impossible, that the satellites are surrounded by atmospheres containing large quantities of aqueous vapor. In support of the last supposition, may be mentioned the spectroscopic observations of VOGEL, who saw traces of the great absorption band which characterizes the spectrum of *Jupiter* in the spectra of the satellites.* Then the water which, in the absence of internal heat, and at the great distance of the satellite from the sun, would, under other circumstances, be frozen, and remain fixed upon the surface, would be vaporized by the heat radiated from the central planet. Hence, we should have the satellite surrounded by clouds in the same manner as *Jupiter* itself, and the albedos of the two bodies would be equal. It would seem that, considering the extreme tenuity of the atmosphere which so small a

* I have not been able to satisfactorily verify this observation myself.

body would possess, the amount of heat required for the existence of such conditions is not in excess of the supply which we may well suppose to be actually afforded by the planet.

In the case of the outer satellites especially, we can, however, readily conceive that the heating effect of the planet is barely sufficient to overcome the cold of space. The cloud layers are, therefore, in unstable equilibrium, and at any moment some accidental disturbance would determine a general precipitation on the side farthest from the source of heat, thereby reducing the albedo of the satellite from its greatest value, that of pure white clouds, to a much lower one, which would have as its minimum that of the surface of the satellite itself. If at such a time the satellite should be projected on the disc of *Jupiter*, we should have the phenomenon of a dark transit. Such transits would evidently be characterized by an irregularity which is actually a feature of their occurrence.

The brightness of the satellite after it has left the disc is not surprising, when we consider how difficult it is to judge of the relative brightness of two surfaces which are not actually in contact. It is quite likely that a very considerable difference could exist under the circumstances of a transit without attracting notice. It might, however, be detected by careful photometric comparisons immediately after the satellite had passed off the disc.

If the satellites should be found to rotate in such a manner as always to present the same side to *Jupiter*, the explanation here suggested might require modification, although it would not necessarily be false. It will probably be conceded, however, that the evidence of such a law of rotation is at present very slight. J. E. K.

On the Explanation of the Dark Transits of *Jupiter's* Satellites.

The recent numbers of the *Publications A. S. P.* have had articles by Messrs. Keeler, Barnard and Hill on the dark transits of *Jupiter's* satellites. These articles refer both to observations and to possible explanations of the phenomena. It appears to me that the simplest way of accounting for these is somewhat as follows:

The albedo of *Jupiter* is 0.62, and the albedos of the satellites are, respectively: I, 0.22; II, 0.27; III, 0.14; IV, 0.08.

For our purposes we may define

$$\text{albedo} = \frac{\text{light reflected per unit-area}}{\text{light received per unit-area}}.$$

The "light received per unit-area" is the same for *Jupiter* and for the four satellites, and the albedos are proportional to the ***mean intrinsic brilliancies*** (the average brightness per unit of area), and may be taken as measures of these brilliancies. That is, we may assume the numerical expression of the average intrinsic brilliancies to be 0.62, 0.22, 0.27, 0.14, 0.08 for *Jupiter* and for I, II, III, IV, respectively.

In my view, the whole explanation of the phenomena of bright and of dark transits depends upon the contrast between the brightness of the satellite (a, for example) and that of the particular part of the planet upon which it happens to be projected (A, B, C . . . . for example).

Suppose a satellite of intrinsic brightness a to approach the limb. It is visible against the sky, because a is many times greater than the intrinsic brightness of the sky. It comes to a part of the limb of *Jupiter* where the brightness is A. If a is much brighter than A, then the satellite appears bright on a relatively dark background. If $a = A$, then the satellite is invisible. If a is much fainter than A (and if the disc of the satellite is of sufficient angular dimensions in the particular telescope employed), then the satellite appears dark on a bright background. As the satellite successively crosses other regions of the planet, B, C, D, etc., other phenomena arise which are to be explained according to the principles just given.

The angular diameters of the satellites are about—I, 1″.08; II, 0″.91; III, 1″.54; IV, 1″.28; I and II being somewhat the smaller, and, therefore, the least likely to be seen dark on a bright background, on this account alone.

I believe it to be a fact of observation that black transits of II have seldom been recorded; that those of I are comparatively rare; while III, and especially IV, are frequently seen dark in transit. It appears to me that the whole explanation of the matter lies in bringing the foregoing facts together. The explanation has nothing novel about it, as it is essentially that of KLEIN* and of YOUNG.†

I have made an (approximate) determination of the intrinsic brightness of various parts of the disc of *Jupiter* which may have some interest in this connection.

On July 8, 1890, at $13^h\ 3^m$ P. s. t., I took an enlarged picture of *Jupiter*, which was again enlarged, so that the polar axis of the planet was 1.55 inches long. A paper print from this latter negative was cut in two along the polar axis, and the different tints along

* *Astronomische Nachrichten*, 2014.

† *General Astronomy*, § 624.

the line of section were compared with a carefully prepared photographic wedge, lent to me by Mr. BURNHAM, which was graduated into thirteen grades.

The wedge was a photographed paper copy of a drawing in india ink, in which the first grade had one wash of color; the second, two washes; the third, three, etc.*

The darker the paper-print of *Jupiter* (and the graded scale) the brighter was the corresponding area of the planet. Beginning at one pole I matched the paper-print of the planet with the grades of the scale, as follows:

0.00 to 0.09	inches:	matches	grade	1
0.09 to 0.25	"	"	"	3
0.25 to 0.33	"	"	"	6
0.33 to 0.42	"	"	"	3
0.42 to 0.54	"	"	"	13 +
0.54 to 0.65	"	"	"	3
0.65 to 0.87	"	"	"	5
0.87 to 1.02	"	"	"	4
1.02 to 1.10	"	"	"	13 +
1.10 to 1.40	"	"	"	4
1.40 to 1.55	"	"	"	1

Leaving out of account all consideration of the errors of the method of comparison and of the errors of the photographic wedge, it follows that the intrinsic brilliancy (photographically) of some portions of *Jupiter's* disc is at least thirteen times as great as the intrinsic brilliancy of the limbs (photographic). It is probably, in fact, even greater than this.

The difference of the *visual* intrinsic brilliancies is by no means so large, but it may safely be said that the brightest parts of *Jupiter's* disc are ten times as bright as the limbs. We know that the satellites of *Jupiter* in transit often appear bright near the limbs, and this will give us an approximate measure of the brightness of the limbs, and hence of the brightness of the most brilliant portions. Taking the numerical expressions of the albedos to be the measures of intrinsic brilliancies, we know that the limbs of Jupiter are sometimes less bright than 0.08 (because Satellite IV sometimes appears bright when it is projected on *Jupiter* near the limbs). Let us sup-

* It is known that owing to the small "range in sensitiveness" of plates, a wedge so prepared will give equal gradations of light over a small distance only; and that the point of the scale where the grades represent equal gradations is a function of the exposure-time.

pose the brightness of the limb to be 0.07. Ten times this brightness would be expressed by 0.70. The *average* brightness of *Jupiter* is expressed by 0.62, and hence it is clear that our estimates are not extravagant.

From the table above, it follows that much of *Jupiter's* surface is not more than three or four times as bright as the limbs; or, numerically, three or four times $0.07 = 0.21$ or 0.28. On a background of brightness 0.21 or 0.28 a satellite of brightness 0.22 (Satellite I) or 0.27 (Satellite II) would usually be lost. There is not sufficient contrast to make it appear either as dark or bright. If, however, any of the satellites chanced to fall on the brightest regions of the planet (brightness $= 0.70$ or greater), they would certainly appear as dark bodies. I take it, therefore, that the only reason why dark transits of II are not recorded (so far as I know), is because they have not been looked for with the proper instruments and precautions.

The preceding explanation appears to me to account for the facts as well as the meager numerical data will allow, and to have an advantage in that it calls for no assumptions whatever. No collection of past observations of dark transits can throw any material light on the question; but future observations of phenomena of the sort will be of value, if they give numerical estimates of the brightness of the backgrounds on which the satellites are projected.

E. S. H.

Note on the Opposition of *Mars*, 1890.

The very severe weather of 1889-90 lasted unusually late into the spring, and the season of excellent nights hardly began before late July or early August. By this time *Mars* was too distant from the earth and too low in the west to be well observed. All available opportunities were utilized in the early parts of the opposition, and the planet was regularly followed during June, July and August. Experiments were tried with colored glasses, with diminished apertures, etc., all with small success. Many photographs of *Mars* were made, but none of any real excellence.

Drawings of the planet were made on April 3d, 9th, 12th, 26th, 30th, May 3d, 11th, 15th, 18th, 21st, 25th, June 5th, 6th, July 6th, August 5th and 6th. In making these drawings three observers usually took part. E. S. H. and J. E. K. always saw the *canals* as dark, broad, somewhat diffused bands. In bad vision they were drawn in this way by J. M. S. also. Under good conditions, however, the

latter observer described them as narrow lines, a second of arc or so in width.

On April 12th J. M. S. saw two of the canals doubled. It may, therefore, be said that the observations of Professor SCHIAPARELLI have been verified by this observer, both as to the narrowness of the canals and as to their duplication. The positions of most of Professor SCHIAPARELLI's canals have been verified by some one of us.

The mystery still remains why two observers should agree in their own observations, and should disagree with a third and with the discoverer of these phenomena. A remark by Mr. KEELER (*Publ.* A. S. P., vol. II, p. 165), with regard to the color-correction of the large telescope and its effect on the seeing of faint planetary markings, throws a little light on this question, but fails to explain how three observers of experience, viewing the same object, with the same instrument, at the same time, can obtain such differing impressions. A review of the observations of *Mars* in 1888 shows that the same observers differed in somewhat the same manner at that time; and an examination of the drawings of E. S. H. from 1875* to 1890 shows that this observer has always drawn the canals in one and the same manner. Letters from Professor SCHIAPARELLI say that he has succeeded in obtaining twelve or fifteen excellent drawings during 1890, which confirm his previous discoveries, and which even extend the area over which the doubling of the canals takes place. E. S. H., J. M. S., J. E. K.

THE FUTURE OF STELLAR PHOTOGRAPHY.

[Extract from a Letter written in 1857 to WM. MITCHELL by G. P. BOND.†]

"As far as I am informed, the attempt to photograph the fixed stars by their own light has been made nowhere else, up to the present date; the rumor of a daguerreotype of a nebula made in Italy some years since was unfounded.

"About seven years since (July 17th, 1850) Mr. WHIPPLE obtained daguerreotype impressions from the image of *α Lyræ* formed in the focus of the Great Equatorial, and subsequently from *Castor*, thus establishing a simple but not uninteresting fact—the possibility of such an achievement. On these occasions a long exposure of one or two minutes was required before the plate was

* See *Mémoires couronnés etc. publiées par l' Académie Royale de Belgique*, vol. XXXI, figs. 1–5 (1875 June–August).

† Professor GEORGE PHILLIPS BOND was then Assistant in the Harvard College Observatory. The extract given above was kindly communicated by his daughters.

acted upon by the light, and in this interval the irregularities of the Munich clock-work were so great as to destroy the symmetry of the images, while the smaller stars of the second magnitude would not 'take' at all.

"For some years after, Mr. WHIPPLE gave his attention to photographs of the moon and sun, and the stars were left to themselves. But improvements in the art progressed rapidly; the preparations were more sensitive; the artists had acquired more experience. At the same time the principle of the spring-governor had been thoroughly tested, and found to supply a great desideratum in imparting a sidereal motion to the telescope, incomparably more uniform than that attained by the Munich mechanism. Messrs. WHIPPLE and BLACK recommenced their trials on star images (taken by the collodion process) in March of the present year, and they are still in progress. The expense of time, chemicals, etc., is far more considerable than one would have anticipated—each night, in fact, opens new vistas requiring exploration. The field for experiment is too vast to be at once occupied, even if we were provided with unlimited means. But the results already obtained in the disconnected attempts we have thus far been enabled to make are of the highest interest, and suggest possibilities in the future which one can scarcely trust himself to speculate upon. Could another step in advance be taken equal to that gained since 1850, the consequences could not fail of being of incalculable importance in Astronomy.

"The same object, α *Lyræ*, which in 1850 required 100 seconds to impart its image to the plate, and even then imperfectly, is now photographed instantaneously with a symmetrical disc, perfectly fit for exact micrometer measurements. We then were confined to a dozen or two of the brightest stars, whereas now we take all that are visible to the naked eye. Even from week to week we can distinguish decided progress.

"Of the beauty and convenience of the method you will scarcely form a correct idea without witnessing for yourself, which I hope you will be able to do before long.

"On a fine night the amount of work which can be accomplished, with entire exemption from the trouble, vexation and fatigue that seldom fail to attend upon ordinary observations, is astonishing. The plates, once secured, can be laid by for future study by daylight and at leisure. The record is there, with no room for doubt or mistake as to its fidelity. As yet, however, we obtain images only from stars to the sixth magnitude inclusive. To be of essential service to

Astronomy, it is indispensable that great improvements be yet made, and these I feel sure will not be accomplished without a deal of experimenting.

"But could we but press the matter on, we should soon be able to say what we can and what we cannot accomplish in stellar photography. The latter limits we certainly have not yet reached. At present the chief object of attention must be to improve the sensitiveness of the plates, to which, I am assured by high authorities in chemistry, there is scarcely any limit to be put in point of theory. Suppose we are able finally to obtain pictures of seventh-magnitude stars. It is reasonable to suppose that, on *some lofty mountain and in a purer atmosphere*, we might, with the same telescope, include the eighth-magnitude. To increase the size of the telescope three-fold in aperture is a practicable thing, if the money can be found. This would increase the brightness of the stellar images, say, eight-fold, and we should be able then to photograph all the stars to the tenth and eleventh magnitude inclusive. There is nothing, then, so extravagant in predicting a future application of photography to stellar Astronomy on a most magnificent scale. It is, even at this moment, simply a question of finding one or two hundred thousand dollars to make the telescope with and to keep up the experiments.

"What more admirable method can be imagined for the study of the orbits of the fixed stars and for resolving the problem of their annual parallax than this would be, if we could obtain the impressions of the telescopic stars to the tenth magnitude? Consider, too, that groups of ten, or fifty even, if so many occur in the compass of the field, will be taken as quickly as one alone would be—perhaps in a few seconds only—and each mapped out with unimpeachable accuracy.

"I have not alluded to two important features in stellar photography. One is that the intensity and size of the images, taken in connection with the length of time during which the plate has been exposed, measures the relative magnitudes of the stars. The other point is that the measurements of distances and angles of position of the double stars from the plates we have ascertained, by many trials on our earliest impressions, to be as exact as the best micrometric work. Our subsequent pictures are much more perfect, and should do better still." * * *

HARVARD COLLEGE OBSERVATORY, 1857, July 6.

Relation between the Colors and the Magnitudes of the Binary Stars.

In 1880 I printed a note on a relation between the colors and magnitudes of the components of binary stars,* in which I showed that when every known case of binary stars of known colors was considered:

I. The components of the 122 binary stars, where the components are of the same color, differ in magnitude, on the average, only $0^m.5$.

II. The components of the 40 binary stars, where the components are of different colors, differ in magnitude, on the average, $2^m.4$.

Mr. W. M. Pierson has recently communicated to the Society an interesting paper on this subject,† which has led me to re examine the table which is printed in my paper. With the help of Mr. Burnham, I have extracted from his "General Catalogue of Double Stars" (which will probably be printed as Volume II of the *Publications of the Lick Observatory*) the distances of the components A and B of each pair of binary stars of the two classes named, I, when A and B are of like color; II, when A and B are of different colors. Omitting the case of 61 *Cygni*, I find that the average distance for class I is about 1".3, while the average distance for class II is about 2".2. It would seem, then, at least possible, that the similarity of the estimates of colors of the stars A and B for class I might arise, on the average, from the difficulty of distinguishing any difference of tint in stars so close together as 1", while the differences of color distinguished in the components of stars of class II might be largely due to the mere fact of their wider separation (2".3 on the average), which would at least tend to make estimations of tint more trustworthy.

I believe it is a fact that it is a physiological peculiarity of the human eye to estimate *faint* stars more blue than they really are. It is also certain that unequal binary stars (where the component A is much brighter than B) are far more likely to be discovered when the distance is 2" or more than when it is 1". Considering these two facts, together with the reasoning which I have given on page 468 of the paper I have cited from the *American Journal of Science*, I am disposed to lay less stress on the conclusions of that paper than formerly, and I think these facts bear on the conclusions reached by Mr. Pierson also. E. S. H.

* *American Journal of Science*, vol. xix, June, 1880, p. 467.

† *Publications* A. S. P., vol. ii, No. 8, p. 105.

Bright Meteor Seen September 10, 1890.

[Extract from a Private Letter.]

* * * "This evening, at 10:15 o'clock, a beautiful meteor passed overhead, tending west. There were four colors plainly visible—green, violet, white and red. The heavens had the appearance of bright moonlight. The light lasted probably twenty or twenty-five seconds. The trail of light left seemed to have a cloudy appearance, and gradually disappeared. The stone ceased to give light at about twelve or fifteen degrees above the horizon, I should judge. There was a soft, rustling sound, like the wave of a piece of silk through the air.

"Hoping that this bit of information may be of use to science, I am, "Yours truly, H. E. Witherspoon."

Ft. Jones, Siskiyou County, Cal., September 10, 1890.

Lancaster's List of Observatories and Astronomers, etc.

M. Lancaster has just printed the third edition (1890) of his very useful and accurate *Liste générale des Observatoires et des Astronomes, des Sociétés et des Revues astronomiques.* For each observatory (Section I) there is given the name, the latitude and longitude, the title, etc., of the last publication, and a list of the persons employed as astronomers, computers, etc. Section II contains short but excellent accounts of the principal astronomical societies; while Section III gives similar accounts of such institutions as the French Bureau of Longitude, the English and American Nautical Almanac Offices, etc. Section IV is devoted to astronomical journals. Section V gives the addresses, etc., of astronomers not regularly employed in observatories, amateurs, etc.; and Section VI gives similar data relating to the leading constructors of instruments. A complete index of names concludes this very convenient volume of 147 pages.

Number of Observers and Computers Employed in the Leading Observatories.

From the work just mentioned I have extracted the following data relating to the number of persons regularly employed in astronomical work—either in observations or calculations:

(The Lick Observatory has five astronomers.) The following-named observatories have five or more regularly employed: Algiers (5), Besançon (8), Bordeaux (6), Brussels (8), Cape of Good Hope (7), Cordoba (5), Greenwich (about 20), Grignon (5), Harvard

College Observatory (36), La Plata (7), Leipzig (9), Lisbon (5), Madrid (6), Marseilles (7), Mount Hamilton (5), Melbourne (8), Meudon (7), Mexico (6), Naples (5), Nice (8), Oxford (5), Palermo (6), Paris (17 astronomers and many computers), Potsdam (7), Pulkowa (16), Rio Janeiro (16), Rome (6), Santiago de Chile (5), Tacubaya (5), Toulouse (5), Vienna (7), Washington (7 observers, 3 computers, 9 naval officers; total 19). E. S. H.

The British Astronomical Society.

"*To the Editor of the* [*London*] *Times:*

"Sir: May I ask that you would call the attention of your readers to the establishment of a new astronomical society?

"It has been long felt that, admirably as the Royal Astronomical Society has always fulfilled its functions, it did not supply the wants of many who were yet greatly interested in astronomy. The subscription is too high, and the majority of papers too advanced for many; whilst as yet ladies are not admitted as Fellows. And, further, the work of organizing and directing amateur observers in astronomical observations lies quite outside the scheme of the Royal Astronomical Society. A society is therefore now in the course of formation, the purpose of which is to secure the more thorough co-operation of astronomical observers throughout the country, and it is hoped that, having a much lower subscription and a less advanced character than the older society, it may meet the need of very many who found themselves precluded from joining the Royal Astronomical Society. Great care will be taken that the new society in no way encroaches on the special province of the older one, to which it may possibly be a strength as a training-ground for new Fellows.

"I am, sir, your obedient servant,

"E. Walter Maunder.

"Hyde-house, Ulundi-road, Blackheath, August 14, 1890."

"The following constitute the Provisional Committee: T. W. Backhouse, F.R.A.S., Rev. John Bone, F.R.A.S., D. Booth, Miss Brown, G. Calver, F.R.A.S., G. S. Criswick, F.R.A.S., G. T. Davis, A. M. W. Downing, M.A., F.R.A.S., P. F. Duke, F.R.A.S., T. G. Elger, F.R.A.S., Rev. T. E. Espin, B.A., F.R.A.S., W. S. Franks, F.R.A.S., W. H. St. Quintin Gage, F.R.A.S., J. E. Gore, M.R.I.A., F.R.A.S., N. E. Green, F.R.A.S., H. Grattan Guinness, D.D., John Haswell, M.A., D.C.L., H. P. Hollis, B.A., F.R.A.S., Rev. F. Howlett, M.A., F.R.A.S., W. Huggins, LL.D., D.C.L., F.R.S., Mrs. Huggins, H. Ingall, F.R.A.S., Rev. S. J. Johnson, M.A., F.R.A.S., J. Harvey Jones, F.R.A.S., S. T. Klein, F.L.S., F.R.A.S., T. Lewis, F.R.A.S., Major E. E. Markwick, F.R.A.S., E. Walter Maunder, F.R.A.S., W. H. Maw, F.R.A.S.,

Arthur Mee, F.R.A.S., W. H. S. Monck, M.A., F.R.A.S., Captain W. Noble, F.R.A.S., J. A. Westwood Oliver, James G. Petrie, F.R.A.S., C. L. Prince, F.R.A.S., W. Schooling, F.R.A.S., G. M. Seabroke, F.R.A.S., K. J. Tarrant, F.R.A.S., Rev. W. R. Waugh, F.R.A.S., and A. Stanley Williams, F.R.A.S."

"This society has been formed to secure more thorough co operation of astronomical observers throughout the country, and at the same time meet the wishes and requirements of many who, though taking a high interest in Astronomy, have found themselves precluded by one cause or another from joining the Royal Astronomical Society. Its leading features are as follows:

"Membership: Open to all persons interested in Astronomy, ladies as well as gentlemen.

"Headquarters: To be fixed in London.

"Objects: The association of observers, especially the possessors of small telescopes, for mutual help, and their organization in the work of astronomical observation. The circulation of current astronomical information. The encouragement of a popular interest in astronomy.

"Methods: The arrangement of memoers for the work of observing in sections or departments of observation, under experienced directors. The publication, at short and regular intervals, of a journal containing reports of the society's meetings and of its observing sections; papers by members; and notes on current Astronomy. The holding of meetings, not only in London, but also at provincial centers, wherever the number of members justifies it and the members themselves desire it."

Notice concerning the Miscellaneous Stars Observed with the Repsold Meridian-Circle of the Lick Observatory.

The meridian-circle is regularly employed by Professor Schaeberle in the observation of stars, of which a list has been given in *Publ.* A. S. P., vol. II, p. 27.

The circle is also employed from time to time in determining the places of stars used for comparisons with comets, planets, etc. For such stars provisional places are derived as accurately as possible with our present knowledge of the constants (refraction, division-error, flexure, etc.), and these provisional places, if published now, may be of use to other observers.

The following list is the first installment of such observations. It is to be understood as giving provisional places only. It is our intention at a future time to bring all such lists, after revision, into a cat-

alogue of miscellaneous stars. The places in this and subsequent lists of the sort are the immediate results of observation reduced to the beginning of the year 1900. For all stars of the *Berliner Jahrbuch* the proper motion as given in that work is applied. All other stars are reduced without proper motion. The refraction and other constants are those given in Vol. I, *Publications of the Lick Observatory*, or else those of the *Berliner Jahrbuch*. No corrections for division are here applied. The separate observations are united into one mean. The *current number* of the star is its R. A. for 1900 to the integral second neglecting decimals, written as a number of six figures. Thus, a star whose R. A. is $1^h\ 24^m\ 1^s.7$ will have the number 012401; one whose R. A. is $23^h\ 7^m\ 20^s$, the number 230720, etc. If several stars should chance to fall on the same second, they will be distinguished as *a*, *b*, *c*, etc., in the order of R. A. for 1900.* The R. A. observations are strictly differential with the *B. J.* system, and, in general, the list of time-stars between $+15°$ and $-10°$ (*Publ.* A. S. P., vol. II, p. 28) is employed. The decl. observations are sometimes strictly differential with the *B. J.* system, but occasionally may be referred to the nadir, with an assumed latitude.

E. S. H.

Gift to the Lick Observatory from Miss Bruce, of New York City.

Miss C. W. Bruce, a member of the Astronomical Society of the Pacific, has presented to the Lick Observatory a sum of money, to be used in employing a computer to aid in the reduction of the meridian observations made at Ann Arbor by Professor Schaeberle upon the double-stars of the *Positiones Mediæ* of W. Struve. These observations will be completed here and published by the Observatory. The generosity of Miss Bruce enables us to begin the reductions of the older observations at once. The gift is a portion of Miss Bruce's Grant in Aid of Astronomical Research, and was awarded through the Harvard College Observatory.

E. S. H.

October 21, 1890.

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* This method has the advantage of allowing other stars to be inserted in their appropriate places, at any time, without disturbing the sequence of numbering. Thus, one and the same star has always one and the same number. As a striking example of the inconveniences of the opposite plan, I may cite the Washington Catalogue of Stars for 1860, where different numbers are assigned to the same star in different editions. Another special advantage of the adopted system of numbering is that when the place of a star is quoted for an epoch different from the catalogue-epoch, as 1910, for example, the number of the star then gives additional and useful data—*i. e.*, the R. A. for 1900 and the (approximate) variation in ten years. The plan has some disadvantages also, but only a trial of it can determine whether the disadvantages outweigh the advantages.

I. List of Miscellaneous Stars Observed with the Repsold Meridian-Circle of the Lick Observatory.

By J. M. Schaeberle.

Catalogue Number.	Mag.	R.A. 1900.	Dec. 1900.	No. of obs. R.A.; Dec.	Epochs, R.A.; Dec. 1800 +	Remarks. Name of the Star in other Catalogues, purpose for which the Star was observed, etc.
		h m s	° ′ ″			″
192200	7.7	19 22 0.48	−5 56 4.3	4. 4.	89.46	S.D. 6.5151
192337	8.3	19 23 37.87	−6 22 43.0	4. 4.	.47	6.5158
192441	8.5	19 24 41.33	−5 7 47.0	4. 4.	.47	5.4985
192553	8.4	19 25 53.20	−5 52 52.6	5. 5.	.48	5.4989
192615	8.2	19 26 15.45	−5 19 42.2	6. 6.	.48	5.4992
192805	7.6	19 28 5.69	−4 57 27.4	5. 6.	89.50	— 5.5006
192912	8.5	19 29 12.60	−4 40 0.3	4. 4.	.47	4.4843
192955	7.8	19 29 55.68	−4 30 41.4	4. 2.	.47	4.4846
193116	7.8	19 31 16.18	−4 59 37.7	1. 1.	.49	5.5021
193128	7.5	19 31 28.29	−4 31 18.4	4. 4.	.46	4.4855
193156	8.0	19 31 56.93	−3 41 53.3	3. 3.	89.50	— 3.4649
193228	5.0	19 32 28.98	−4 52 14.3	7. 7.	.47	4.4861
193502	6.8	19 35 2.11	−5 40 39.4	4. 4.	.49	5.5036
193528	7.5	19 35 28.37	−4 15 52.6	3. 4.	.49	4.4877
193630	7.7	19 36 30.92	−4 31 20.1	8. 8.	.47	4.4883
193958	8.3	19 39 58.65	−4 45 49.9	6. 6.	89.46	— 4.4903
194134	7.8	19 41 34.25	−3 54 26.6	4. 4.	.48	4.4916
194228	7.8	19 42 28.45	−5 28 48.3	4. 4.	.48	5.5060
194339	7.8	19 43 39.43	−4 44 42.7	8. 8.	.47	4.4926
194418	8.0	19 44 18.79	−4 46 49.2	5. 5.	.47	4.4936
194531	6.5	19 45 31.20	−4 56 50.1	4. 4.	89.48	— 5.5075
194802	8.0	19 48 2.15	−4 49 53.2	6. 6.	.47	4.4960
194857	8.0	19 48 57.46	−5 18 19.8	7. 7.	.47	5.5099
195200	8.2	19 52 0.86	−4 57 11.0	5. 5.	.47	5.5120
195238	8.5	19 52 38.61	−5 27 15.5	5. 5.	.48	5.5124
195253	8.2	19 52 53.46	−6 37 11.9	2. 3.	89.47	— 6.5320
195254	8.2	19 52 54.25	−4 37 29.1	2. 2.	.48	4.4984
195532	7.8	19 55 32.18	−4 35 6.4	4. 5.	.47	4.4992
195615	8.2	19 56 15.16	−6 39 3.0	4. 4.	.47	6.5339
195652	6.3	19 56 52.72	−5 16 1.7	3. 3.	.47	5.5138
195740	8.1	19 57 40.46	−7 58 26 9	4. 4.	89.47	— 8.5205
195756	8.2	19 57 56.71	−4 54 40.3	3. 3.	.49	5.5144
195959	8.5	19 59 59.23	−6 52 7.7	3. 3.	.49	6.5360
200119	7.2	20 1 19.69	−4 42 13.2	3. 3.	.47	4.5016
200122	8.2	20 1 22.16	−7 18 4.4	4. 5.	.48	7.5169
200139	7.3	20 1 39.48	−8 28 8.1	2. 2.	89.52	— 8.5237
200544	6.5	20 5 44.77	−9 8 18.0	4. 6.	.47	9.5382

Comparison Stars for Victoria, 1889.

Printer's Error in Professor Weinek's Paper on Drawings of the Moon.

On page 214, No. 2, *for* Sinus Iridium *read* Sinus Iridum.

DEATH OF CAPTAIN RICHARD S. FLOYD, LATE PRESIDENT OF THE LICK TRUSTEES.

Captain R. S. FLOYD, President of the Lick Trustees from 1876 to the present time, died suddenly in Philadelphia on the 17th of October, at the age of 47 years. He had been closely connected with the Lick Observatory, almost from the very beginning, and his name will always be honorably associated with its early history. The following paragraphs from the Introductory Note to the first Volume of the Publications of the Observatory (1887) exhibit clearly the nature of the work accomplished under his direction:

"The completion of the task entrusted to the Lick Trustees by the provisions of Mr. LICK'S Deed of Trust is now apparently near at hand. This task was to construct and erect 'a powerful telescope, superior to and more powerful than any telescope ever yet made, with all the machinery appertaining thereto, and appropriately connected therewith, * * * and also a suitable observatory.'

"The present Board of Trustees was appointed September 2, 1876, and has had this object in view continuously for the past ten years. In the course of this time members of the Board have visited many of the leading observatories of this country and of Europe; the principal astronomers of the world have been advised with personally and by correspondence; thousands of letters have been written to them, to architects, contractors, builders and instrument makers; and every detail of the construction and equipment of a vast astronomical establishment on the summit of a mountain four thousand feet in height and twenty-six miles distant from the nearest town, has been personally superintended.

"It is impossible to convey in a few words any adequate idea of the multiplicity of separate interests which have been considered—from those of the practical astronomer to those of the day-laborer; nor of the distressing legal complications which have arisen and which are now happily settled; but it will be found to be interesting by those who will read this and subsequent volumes of the Observatory Publications, to remember the very exceptional nature of the duties confided to us.

"We have been obliged to make the summit of Mount Hamilton accessible by a road twenty-six miles long, to remove more than 70,000 tons of material in order to get a level platform large enough for the instruments to stand upon, to arrange a good and sufficient water supply on the top of a barren mountain, to maintain and pro-

vide for workmen of all classes, and to carry out in the best and most economical manner the real object of our trust, which was to present to the world an astronomical observatory of the highest class, which should be permanently useful to science.

"The difficulties were not simply those of a practical nature. At the very beginning of our work it was a matter to be seriously considered whether the most powerful telescope ought to be made as a refractor or as a reflector. The providing of the rough glass discs has itself required six years, and has only been accomplished after twenty unsuccessful trials. The plans of the Observatory buildings had to be settled upon, so as to accomplish our objects in the most efficient and at the same time in the most economical manner.

* * * * * * * * * *

"The present volume is designed to be the first of a series of Publications of the Lick Observatory. In it will be given a brief description of the Observatory in its present state, and a short history of the work which has been done. * * * * *

"More detailed and more purely scientific investigations of the various instruments will be given in future volumes. This one may serve as a register of progress up to this time, and as an introduction to a series of astronomical works which are to result from the generous gift of JAMES LICK to his fellow-citizens of California."

Captain FLOYD was not only the President of the Trustees, but also was specially in charge of the construction of the Observatory, and to this task he brought his best abilities and most faithful service. No one knows better than the writer of these lines how much the institution is indebted to his unfailing interest, to his quick intelligence, and to his honest purpose.

His character was such that those brought near to him loved him. And no difference of opinion could shake this affection.

When the history of the Lick Observatory comes to be written, the name of FLOYD must hold a conspicuous and honorable place in its annals.

EDWARD S. HOLDEN.

1890, October 18.

Minutes of the Meeting of the Board of Directors, held in San Francisco, (at 232 Sutter Street), November 29, 1890.

A quorum was present. The minutes of the last meeting were read and approved.

The following members were duly elected:

List of Members Elected November 29, 1890.

John S. Adam,	Canaan, Connecticut.
Dr. G. Barroeta,	San Luis Potosi, Mexico.
Wm. Andrews Brown,	Newton, Mass.
Principal B. G. Clapp,	Fulton, New York.
Dr. E. S. Clark,	16 Geary Street, S. F. Cal.
Homer A. Craig,	1325 Alice Street, Oakland, Cal.
H. W. Faust,	618 Harrison Street, S. F., Cal.
Lieut. John P. Finlay, U. S. A.,	Signal Office, S. F., Cal.
President M. P. Freeman,	University of Arizona, Tucson, Ariz.
General John Gibbon, U. S. A.,	Headquarters Military Division of the Pacific, S. F., Cal.
J. J. Gilbert,	U. S. C. & G. Survey, Box 2512, S. F., Cal.
L. Gilson,	211 Sansome Street, S. F., Cal.
G. J. Hicks, E. M.,	31 Clinton Avenue, New Brighton, Staten Island, N. Y.
Maures Horner, F. R. A. S.,	Mells, Frome, Somerset, England.
James E. Ingraham,	President S. Florida Railroad Co., Sanford, Florida.
Professor Martin Kellogg,	University of Cal., Berkeley, Cal.
E. B. Knobel, Secretary R. A. S.,	Bocking, Braintree, Essex, England.
C. F. de Landero,	Box 34, Guadalajara, Mexico.
W. B. Mayes,	1127 Lincoln Place, Los Angeles, Cal.
Fremont Morse, U. S. C. & G. Survey,	Box 2512, S. F., Cal.
H. F. Newall,	Observatory of the University, Cambridge, England.
P. Noordhoff,	Groeningen, Holland.
John A. Parkhurst,	Marengo, McHenry Co., Ill.
Thomas Prather,	Pres. Union Savings Bank, Oakland, Cal.
L. A. Rockwell,	Traver, Cal.
G. N. Saegmuller,	Care of Fauth & Co., Maryland Avenue, Washington, D. C.
Herman Schussler,	Pacific-Union Club, S. F., Cal.
Hon. Demas Strong,	71 Broadway, Brooklyn, N. Y.
Dr. J. Muñoz Tébar,	Carácas, Venezuela, or 234 E. 116th Street, New York City.
M. A. Veeder, M. D.,	Lyons, New York.
G. A. Wood, M. D.,	Traver, Cal.

A number of members were proposed for election January 1, 1891; and the list was laid over till the January meeting of the Directors.

It was *resolved* that the question of forming a fund from the fees for life-membership be referred to a Committee consisting of Messrs. SCHAEBERLE, PIERSON, MOLERA, HILL and HOLDEN, to report at the next meeting;

Resolved that the Library Committee be empowered to furnish the new rooms of the Society;

Resolved that the Publication Committee be empowered to exchange the *Publications* A. S. P. with other journals of like nature.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC HELD AT 232 SUTTER STREET, SAN FRANCISCO, NOVEMBER 29, 1890.

The President in the Chair.

The minutes of the last meeting were read and approved.

A list of presents received was read by the Secretary, and the thanks of the Society were voted to the givers.

A list of new members elected was also read by the Secretary.

The following papers were announced:

a. "The Law of the Solar Corona," by Professor FRANK H. BIGELOW, of the Nautical Almanac Office, Washington, D. C.

b. "Coronal Extension," by C. M. CHARROPPIN, S. J., University of St. Louis, Mo.

c. "Observations and Drawings of Saturn, 1879 to 1889," by Professor EDWARD S. HOLDEN, Lick Observatory.

d. "The Observatory of Swarthmore College," by Miss S. J. CUNNINGHAM, Director.

e. "The Kenwood Physical Observatory" (Chicago), by GEORGE E. HALE, Director.

f. "Work at the Lick Observatory 1888 to 1890," by Professor EDWARD S. HOLDEN, Director.

g. "An Account of an Experiment made to determine whether Gravitation Force varies with the Temperature," by A. E. KENNELLY, of Orange, N. J.

h. "Index-Map of the Moon," by Professor C. A. YOUNG, Director of the Halstead Observatory, Princeton, N. J.

The paper (*f*) was read. The others will be printed in the *Publications* A. S. P.

Adjourned.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year.

It is intended that each member of the Society shall receive a copy of each one of the Publications for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title page and index of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied to members, so far as the stock in hand is sufficient, on the payment of one dollar to either of the Secretaries.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," at the rooms of the Society, 408 California Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. II. SAN FRANCISCO, CALIFORNIA, DECEMBER 31, 1890. NO. 12.

INDEX TO VOLUMES I AND II.

(Numbers 1-12; 1889 and 1890.)

[Arranged Alphabetically by Authors and Subjects.]

BY EDWARD S. HOLDEN.

NOTE: It is the present intention of the Committee on Publication to print a General Index to the Publications A. S. P. every ten years, in the volumes for 1890, 1900, 1910, etc. The accompanying Index is a beginning in this direction, and the compiler asks indulgence for its faults of omission or of commission.

CORRIGENDA TO VOLUME II.

Page 24: The R. A. and Dec. are for 1855.0.

" 41: Remove the title-page preceding page 41.

" 50: The woodchoppers in the Sierra Nevada have found, by examining the injuries to the trees felled there, that it has been about one hundred years since so much snow fell in the main range. The injuries to trees on Mt. Hamilton seem to indicate something of the same sort, although no large trees have been felled and their rings of annual growth counted. The conclusion is that the winter of 1889–90 was the severest for a century, so far as snowfall is concerned. The winter of 1861 is the only one since 1849 which can be compared with it.

" 85: The errata in the addresses of members will be corrected in the next published list.

" 99: lines 20–22, *for* 143, 248, 194, 175 *read* 194, 248, 175, 143.

" 126: *for* Astronomische *read* Astronomischen.

" 139: *for* N. H. HEMING *read* N. H. HEMIUP.

" 204: (last lines) *for* "it shows an astonishing amount of detail, which requires no explanation and" . . . . *read* "of detail, independently registered and"

" 205: line 6; *for* 0".97687 *read* 0".95687.

" 209: (middle of page) *for* "twenty-five times" *read* "two hundred times"

" 214: No. 2; *for* Sinus Iridium *read* Sinus Iridum.

" 257: line −16; omit *Lyra*.